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An objective, statistical synoptic weather map classification scheme developed by Lund to stratify map patterns for further study was used to type regional weather patterns. The investigation extended over a 500-mile radius of the greater St. Louis area and was intended for subsequent application to air pollution studies. This analysis correlated sea level pressure data at 21 selected National Weather Service stations at a specified time on a given day, with sea level pressures for these same stations on each of the other days in the four-year period 1973 through 1976. A total of 52 separate weather map types were identified with 12 map types in the winter season, 13 map types in the spring season, 13 map types in the summer season, and 14 map types in the autumn season.

To illustrate the potential usefulness of this method to air quality and synoptic weather relationships, a preliminary comparison of the weather typing system to suspended particles and carbon monoxide concentrations was also made.

Results indicate that the typing program is able to show that synoptic-scale weather does affect relative pollution levels in the St. Louis region, if definitive synoptic model types are carefully chosen prior to application to pollutatn concentration levels.

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ABSTRACT

An objective, statistical synoptic weather map classification scheme developed by Lund to stratify map patterns for further study was used to type regional weather patterns. The investigation extended over a 500-mile radius of the greater St. Louis area and was intended for subsequent application to air pollution studies. This analysis correlated sea level pressure data at 21 selected National Weather Service stations at a specified time on a given day, with sea level pressures for these same stations on each of the other days in the four-year period 1973 through 1976.

A total of 52 separate weather map types were identified with 12 map types in the winter season, 13 map types in the spring season, 13 map types in the summer season, and 14 map types in the autumn season.

To illustrate the potential usefulness of this method to air quality and synoptic weather relationships, this paper also contains a preliminary comparison of the weather typing system to air quality data. The data include total suspended particles and carbon monoxide concentrations sampled in the Regional Air Monitoring System of the Environmental Protection Agency, for a period of approximately a year and a half during 1975-1976.

Results indicate that the typing program is able to show that synoptic-scale weather does affect relative pollution levels in the St. Louis region, if definitive synoptic model types are carefully chosen prior to application to pollutant concentration levels.

Continued research is expected to indicate clearly not only how air pollution levels in the St. Louis area depend on prevailing synoptic weather patterns in general, but also how mesometeorological variables act as diffusion parameters.

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Finally, the senior author wishes to point out that this report is to a significant degree the thesis research program carried out by Mr. Boyle during his program of study toward the Master of Science degree in Engineering, and a large part of Mr. Boyle's thesis is used directly in this final report.

SECTION 1

INTRODUCTION

Air quality, as characterized by air pollutant concentrations, is controlled to a significant degree by the prevailing weather conditions from the time of the initial pollutant emission to the time of sampling and measurement of the atmospheric concentrations. Although the meteorological factors affecting such pollutant dispersal exhibit a wide range of size and time scales, the dispersion field is strongly linked to the synoptic scale of atmospheric motion as a prime feature of the dispersion. The impact of synoptic weather patterns, in this regard, is not new and has been treated widely in numerous books and articles in both the fields of air pollution and meteorology. Recently, synoptic influences have figured prominently in studies of urban plumes, ozone transport via an anticyclonic model, and general "air mass transport".

HISTORICAL BACKGROUND

Accounts dating back to about 300 B.C., such as De Ventis by Theophrastus of ancient Greece, (Coutant and Eichenlaub, 1975), clearly demonstrate man's early attempts to characterize the weather in two easily recognizable patterns. Through the following centuries observant scientists were able to describe various storm models and typical types of weather systems. Modern synoptic meteorology moved ahead rapidly after the development of the polar front storm models. As extended range forecasting techniques were developed in the 1930's and 1940's there was considerable interest in methods to organize weather patterns into sets of synoptic types. The results of these procedures could serve as valuable forecast aids and as a surrogate for the memory of the forecaster.

Rigorous attempts to classify synoptic weather by types, especially in the three decades prior to 1950, have been discussed at some length by Elliott (1951). A six-day North American weather type scheme was developed by Elliott and Krick during the 1930's wherein each identifiable type covered a sequence of days characterized by easily identifiable quasipermanent meteorological factors. Further refinement of this technique resulted in the California Institute of Technology catalogue of synoptic weather types of North America which contained some 20 to 30 distinct types (Krick and Elliott, 1940).

As machine methods moved onto the scientific scene during the 1950's, the arts and skills of forecasting were integrated with the computerized meteorological statistical method of forecasting and analysis. Thus, it was through a natural progression of events that investigators tried computerized statistical methods in developing weather types of generalized synoptic situations. Typical pressure patterns lend themselves to numberical analysis which then can be readily programmed into a computer system.

Application of simple linear correlation statistical procedures, augmented by computer programming, resulted in a workable scheme by Lund (1963) of synotic weather classification which is the major basis for the experimental procedures described in this report. Basically, Lund's technique involved correlating sea level pressure values at 22 northwestern United States weather stations by statistical means to describe recurrent synoptic map patterns. He developed a catalogue of map types which he believed would be most useful in identifying reappearing map patterns and stratifying situations for further study. Since publication of his technique in 1963, several additional investigators have used modifications of his method. For example, Singh, et. al., (1978) have employed a qualification of Lund's style in analyzing synoptic climatology.

Although Lund considers this map typing scheme to be objective, in a 1971 study relating 850 mb data correlations with areal precipitation patterns for California and the eastern United States, he admits that it is difficult to arrange types in a meaningful order with regard to a particular weather event. For example, a meteorological model to estimate the probability of precipitation has not been developed as yet. On a smaller or mesometeorological scale, Christensen and Bryson (1966) employed a variation of a weather typing mathematical modeling procedure, which they called component analysis (factor analysis), that reduced a sample of data for Madison, Wisconsin, to the number of variables needed to describe each day (type) meteorologically. They then compared these variables with the synoptic situation for that day to determine whether the models with certain meteorological factors formed a reasonable synoptic pattern. The results were then grouped, after some manipulations, into synoptic types by the Lund technique. Several papers written by foreign investigators such as Zdravko (1968), Fliri and Schuepp (1968) and Bardin (1971) also refer to Lund's method in their particular development of weather types using additional meteorological parameters of temperature, precipitation, duration of sunshine and cloudiness.

APPLICATION OF WEATHER TYPES TO AIR QUALITY

Although air pollution patterns are generally considered to be influenced to a significant degree by local meteorological conditions, they are also greatly affected by regional and large-scale synoptic weather systems that move through the area. For example, a quasi-stationary anticylonic circulation and in the summer season usually correlates positively with high or even episodic air pollutant concentrations. Conversely, cyclonic circulation is conducive typically to good dispersion and low concentrations of air pollutants. There are many possible variations in the area of air pollution and synoptic weather as shown by the fact that spring time trough situations, quasi-stationary low pressure systems, and weak frontal systems were found to correlate with significantly elevated 2,4-D concentrations by Peckenpaugh, et. al. (1974) in their investigation of long distance atmospheric transport of the organic herbicide in central Washington State.

During the summer of 1974, Westberg, et. al. (1978) conducted a 24-day experiment in Canton, Ohio, involving a vertical and horizontal profile study of ozone concentrations. As a result of their observations of ozone behavior, an ozone transport model was developed which logically explains long-range ozone transport dispositions occurring in a quasi-stationary high pressure situation through the eastern region of the United States. Subsequently, using a mesoscale approach, relationships between sea breeze effects and ambient ozone concentrations were examined by Westberg, et. al. (1975) along the New England coastline. It was found that this phenomenon could either moderate or enhance pollution levels in the Boston area. However, in the Groton, Connecticut region, high concentrations of ozone usually coincided with the sea breeze effects, and aircraft measurements over the ocean indicated that these high concentrations were part of a large urban plume from the New York City - New Jersey area. Since synoptic weather patterns greatly influence this type of atmospheric effect, a map typing classification method should also have practical applications in these cases.

In trying to establish causal relationships between precipitation patterns and the industrial effects of producing steel near Dunaujvaros in central Hungary, Lowry and Probald (1978) concluded that there is a need for both statistical testing of temporal differences, i.e., the pre-industrial period (1934-43) versus the post-industrial period (1961-70), and a synoptic classification method, in exploring definitive anthropogenic effects of precipitation using standard climatological data.

Traditionally, meteorological forecasters have incorporated, consciously or subconsciously, synoptic weather types of significant atmospheric trends into their analysis and prognosis procedures. It is necessary for meteorologists to scrutinize more closely the effects on air quality of definitive weather patterns and for weather forecasters to appreciate the implications involved in this process. As mentioned earlier, we believe that it is extremely important in conducting efficient air pollution control strategy programs that synoptic weather patterns be given consideration as a major influence in the dispersion region.

STUDY OBJECTIVES

One of the primary goals of this research was to identify synoptic weather types by using Lund's objective technique of correlating sea level pressures. Thus a set of seasonal weather map types was developed for application to an experimental area around St. Louis for the time period covered by the Regional Air Pollution Study (RAPS) program.

An additional aim of the study was to begin to understand the relationships of synoptic weather patterns to ambient air pollutants in the St. Louis area. For this purpose, total suspended particles (TSP) and carbon monoxide (CO) data from the EPA St. Louis RAPS program were compiled and analyzed. These particular pollutants were selected mainly because they are relatively inert and easily analyzed. The actual air monitoring data were collected by the Regional Air Monitoring Study (RAMS) which was one part of the overall RAPS program.

In our weather typing research, a tentative analysis of the Greater St. Louis area air quality, as related to synoptic weather, was undertaken as a first step in stratifying air pollution concentration levels into more homogeneous meteorological classifications. It is expected that this library of weather types can be generally useful in assessing air pollution, mesoscale precipitation, and other weather related factors in the St. Louis area.

The results of this research on regional weather systems should provide other investigators working with RAPS data with an objective classification of the prevailing weather systems. Emphasis of synoptic influences on RAPS air pollution situations should increase the realization of the importance of this phenomenon so that more reliable evaluations can be made of air pollution in the St. Louis area. The research program at WSU is continuing with additional and more detailed analyses.

SECTION 2

RESEARCH TECHNIQUES AND RESULTS

SYNOPTIC WEATHER MAP TYPING TECHNIQUE

Weather typing processes in the recent past have been limited mostly to subjective applications and techniques by individual meteorologists.

The advent of computers has not only made possible much more objective synoptic typing systems, but has enhanced the development of large scale dynamic modeling procedures that are more highly sophisticated and useful than the older typing techniques. In this regard, statistical computerized map typing is particularly useful for some specialized situations. Lund (1963) has clearly demonstrated how a simple linear correlation technique can be applied on a mesoscale to develop such a system of synoptic map types. In his study identifying maximum linear correlations between precipitation and the 850 mb surface level, Lund (1971) illustrated the usefulness of map typing in understanding the occurrences of precipitation and cloudiness in the region that was being analyzed. Additionally, regional and hemispheric circulation patterns have been examined in a study by Arai (1964) in which he classified ten years of daily winter 500 mb patterns into fundamental and subsidiary weather types. Methods of weather typing were also used by Halter (1976) in an assessment of weather conditions affecting the Pacific Northwest coast.

As stated previously, the synoptic map typing program described in this study used the statistical or pressure correlation method developed by Lund (1963). Specifically, the area included in the typing program was the region of approximately 500 miles (800 km) radius centered on St. Louis, Missouri. The weather data for the typing process were obtained from 21 first-order National Weather Service stations distributed more or less uniformly over the region. Figure 1 shows the network of stations and the region covered by the sea level pressure analysis used in the program. Table 1 identifies the stations according to their National Weather Service call letter identifiers. Data for the map classification process covered the four-year period, 1973-1976. For this analysis, the sea level pressures at 0000 GMT (6 PM CST) were used in the map typing program. This specific time was chosen to avoid early morning radiation stability influences and to include to the maximum extent possible the full impact of the daily synoptic weather situation on the pollutants under investigation.

The total number of synoptic weather stations employed in this type of appraisal is a compromise between the technical value of a very dense network and the costs of accumulating, handling, and processing the data file. Lund's (1963) initial study used a set of 22 stations over the area along the

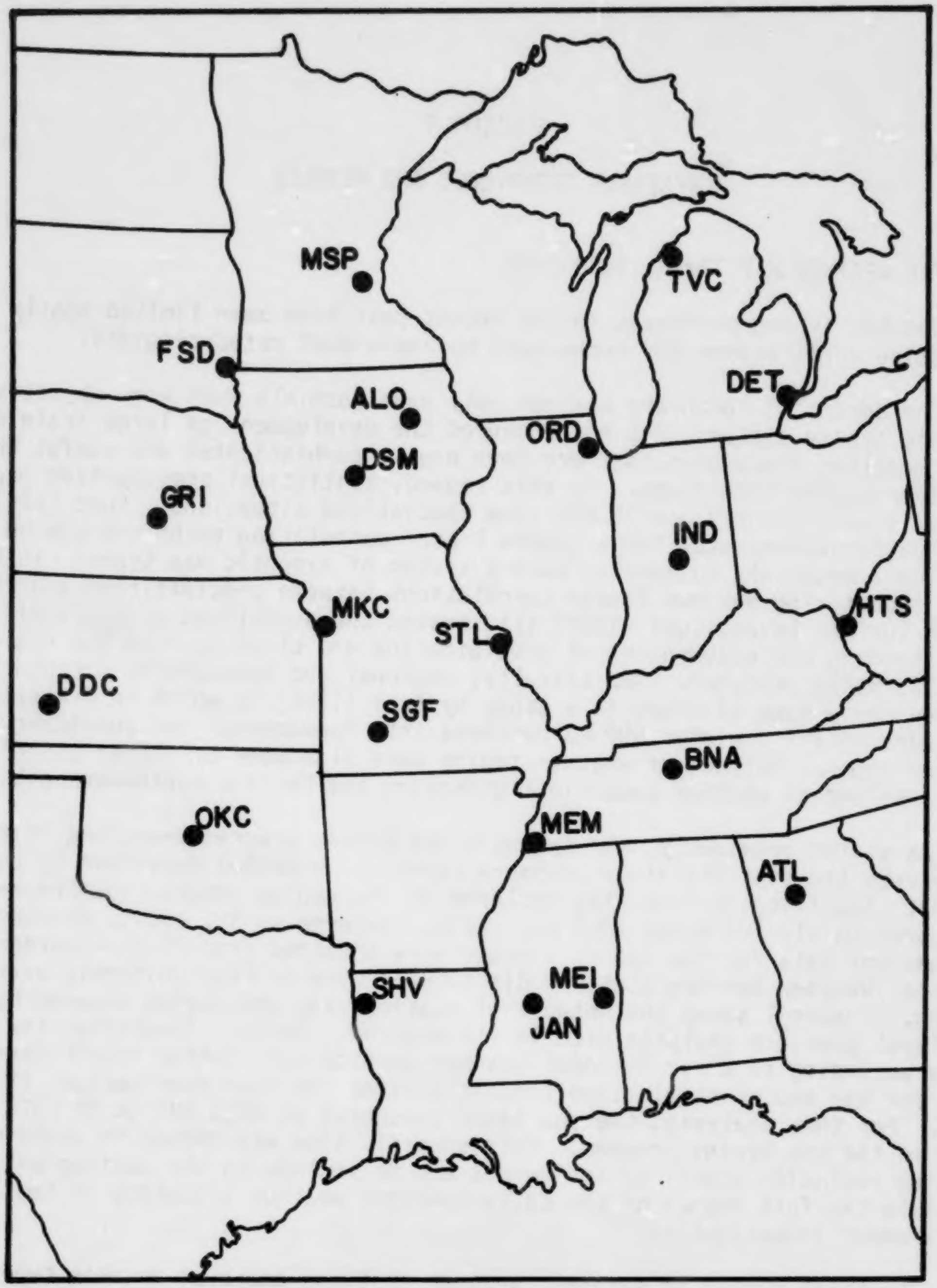

Figure 1. National Weather Service stations used for weather map typing program.

TABLE 1. STATIONS USED IN THIS STUDY*

Call Letters	Name of Station
ALO	Waterloo, Iowa
ATL	Atlanta, Georgia
BNA	Nashville, Tnnessee
DDC	Dodge City, Kansas
DET	Detroit, Michigan (Wayne County)
DSM	Des Moines, Iowa
FSD	Sioux Falls, South Dakota
GRI	Grand Isle, Nebraska
HTS	Huntington, West Virginia
IND	Indianapolis, Indiana
JAN	Jackson, Mississippi
MEI	Meridian, Mississippi
MEM	Memphis, Tennessee
MKC	Kansas City, Missouri
MSP	Minneapolis, Minnesota
OKC	Oklahoma City, Oklahoma
ORD	Chicago, Illinois (O'Hare Int'l.)
SGF	Springfield, Missouri
SHV	Shreveport, Louisanna
STL	St. Louis, Missouri
TVC	Traverse City, Michigan

*All stations are hourly-reporting National Weather Service Stations.

northeast coast of the United States from Virginia to Maine and west to Detroit and Sault Ste. Marie. Halter's (1976) typing program of the Pacific Northwest also used a set of 22 stations covering the area bordered roughly by Quillayute, Washington; Great Falls, Montana; Bryce Canyon, Utah; and Oakland, California. Because about 20 stations have provided a useful typing program, the present study around St. Louis used a total of 21 first-order National Weather Service stations over an area borderd by the neighborhoods of Minneapolis, Minnesota; Huntington, West Virginia; Atlanta, Georgia; Shreveport, Louisiana; and Dodge City, Kansas.

The prior analysis by Lund (1963) was based on five years of winter season data incorporating the months of December through March. Halter (1976) used four full years of data, 1970 through 1973, divided into a winter half, November through April, and a summer half, May through October. In order to insure that the selection of months for each season coincided with the natural mean seasonal temperature pattern for the St. Louis area, an actual temperature plot covering the four-year time period of this study was made to determine if the lowest temperature actually occurred in December, January and February and if the highest temperatures occurred in June, July and August. This proved to be the case, and it was concluded that the season groups selected for this investigation were compatible with expected seasonal temperature cycles.

A map type is a group of weather maps with a sea level pressure pattern distinctive enough to be classified separately from other weather patterns. In terms of identified map types, Lund (1963) had ten types with 398 out of a total of 445, or 89% being successfully typed. Halter (1976) was able to type 92% of his winter seasons into ten types and 94% of his summer season maps into eight types. As will be discussed, the St. Louis typing study had comparable results and typed between 89% and 91% of the seasonal maps into 12 to 14 different types. Thus, the St. Louis program produced results that are generally equivalent to those of similar studies.

The simple linear correlation procedure of Lund (1963) is based on the statistical interdependence between the sea level pressures at a given set of stations on one day and the pressures at the same stations on a second day. For example, in the St. Louis program, if the X-axis (abscissa) is used to plot station pressures for day 1 and the Y-axis (ordinate) the pressures for day 2, the pressure data from 21 stations will define a corresponding set of 21 points in the X-Y field. Standard statistical techniques can then be used to determine the correlation between station pressures on day 1 versus those on day 2. It is assumed, then, that a "good" correlation between station pressures on the two days is indicative of similar synoptic map patterns on the two days. In Figure 2, the correlation coefficient is 0.81 between June 1, 1973 and June 7, 1973 data.

Previous statistical typing by Lund (1963) and by Halter (1976) were based on weather types being identified by correlations of 0.70 or greater between each map date within the type and the identified base map. The choice of magnitude of the lowest acceptable correlation for determining a type classification was examined in detail by Lund (1963). He determined that the same key or base maps would be identified with the use of either 0.90 or 0.80

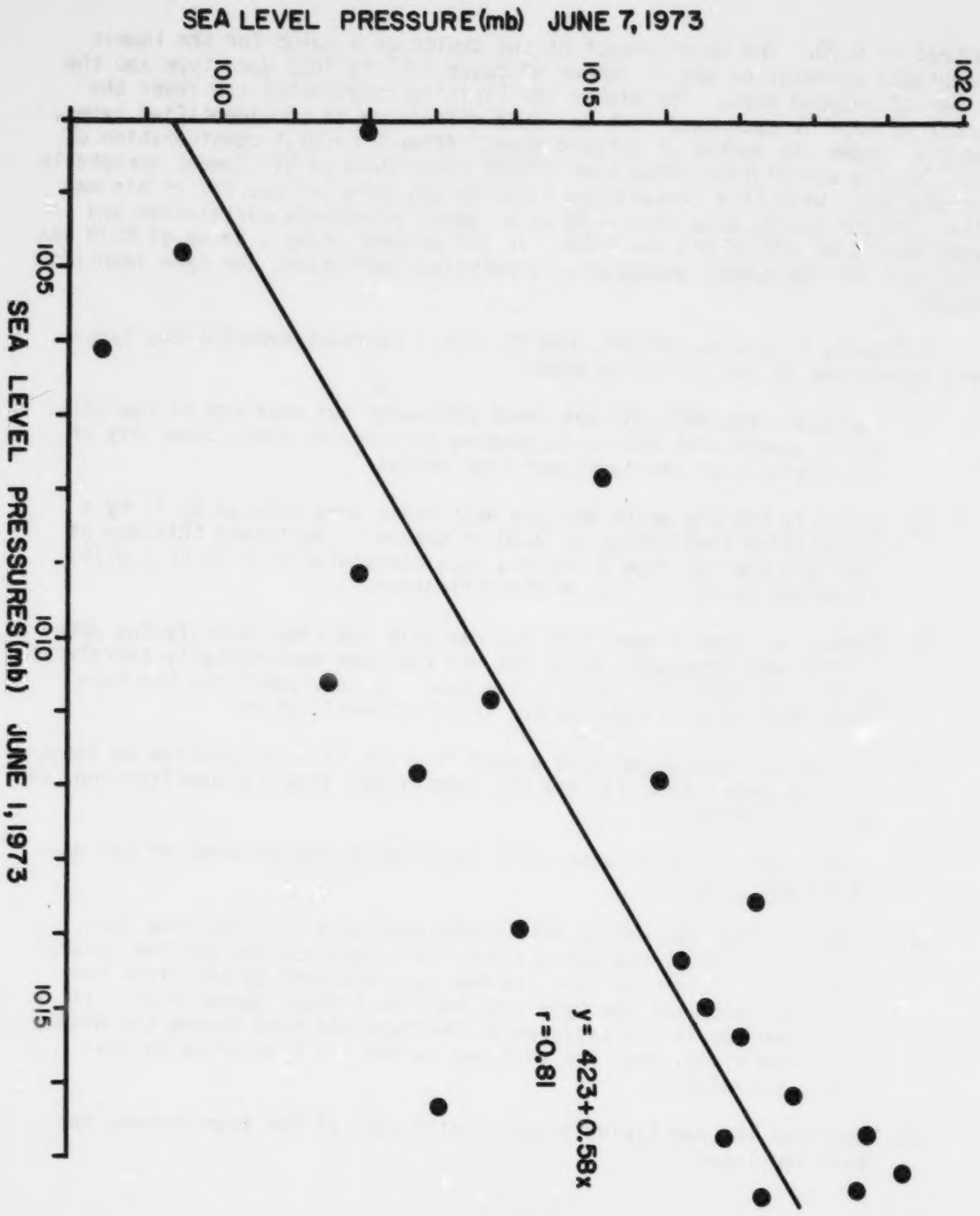

Figure 2. Correlation between network sea level pressures on June 1, 1973, summer Type A base map and June 7, 1973, another summer Type A map.

instead of 0.70. The major impact of the choice of a value for the lowest acceptable correlation was in number of cases falling into each type and the number of untyped maps. The higher the limiting correlation the fewer the number of maps in each case, but not much difference in the identified types, and the larger the number of untyped maps. After a careful consideration of the limiting correlation value Lund (1963) chose 0.70 as his lowest acceptable correlation. With this correlation limit he was able to type 89% of his map file. Halter (1976) also used 0.70 as a lowest acceptable correlation and typed more than 92% of his map file. In the present study a value of 0.70 was also used for the lowest acceptable correlation coefficient for type identification.

Following Lund's guidelines, the St. Louis regional synoptic map types were determined by the following steps:

1. Correlate the 0000 GMT sea level pressures for each day of the selected season with the corresponding pressure on every other day of the season over the four-year test period.

2. Identify the day which has the most other days related to it by a correlation coefficient of 0.70 or greater. Designate this day as the base map for Type A and the maps correlated with it ($r \geq 0.70$) as belonging to the Type A classification.

3. Remove all Type A maps from the map file and then identify the date in the remaining maps which now has the most maps suitably correlated ($r \geq 0.70$) with it. This is the base map for Type B and the maps correlated with it make up the Type B classification.

4. Remove all Type A and Type B maps from the file and proceed to identify the Type C base map and the maps in the Type C classification, as was done for B.

5. Repeat the typing process until most (about 90% or more) of the maps have been typed.

6. Since a given map may be well correlated with more than one type, review all calculated correlations relating each map and the several base maps. Determine that the map type assigned by the first correlation check was the type that had the highest correlation. If the given map is not assigned to the base map type having the highest correlation, move the test map to the map type which is most highly correlated.

7. Continue the map typing process until each of the four seasons has been completed.

SYNOPTIC MAP TYPING RESULTS

In this study, the WSU AMDAHL 470V/6-II computer system was used for the correlation analysis of daily station pressures. The four years of data, 1973-1976, were separated into the four conventional seasons: Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, November.

When this correlation-typing procedure was carried out on a seasonal basis for the region around St. Louis, the result was the identification of 12 winter map types, A(W) through L(W); 13 spring map types, A(SP) through M(SP); 13 summer map types, A(S) through M(S); and 14 autumn map types, A(A) through N(A). Thus, there were a total of 52 map types, although similar map types may occur in more than one season. Those maps in each season not significantly correlated with any identified type were classified in a miscellaneous group designated O.

Some of the specific results of this statistical correlation typing process are shown in Table 2 which lists the assigned map type, the date of the major synoptic pressure system which was the base map of highest correlation factor for the type, and the number of other maps that were most highly correlated with the base map. Typically, the number of maps in a given class decreases from a maximum for Type A, but there are some cases such as the spring (SP) types after F where this does not occur. This is caused by the shifting of maps to the type class with which they show the maximum correlation (see Step 6 in the above typing process and Lund (1963), (Table 3).

The synoptic map types for each season on a daily basis are shown in Table 3, Daily Map Type Assignments, for the four-year test period, 1973-1976. The map types marked with an asterisk are the base or primary map types with the highest correlation factor of a particular season. There is only one date, July 31, 1975, for which there was no map type. This was due to missing sea level pressure data. The file of 52 seasonal base or key map types resulting from this study are reproduced in Appendix A.

The maps presented in Appendix A are the NOAA/NWS United States surface analysis for 0000 Z. As such they cover a larger area and present more data items than was used in the present computer typing system. This was done for the convenience of the meteorologist using this map type file and who would probably be interested in the relationship of the St. Louis regional weather type to the synoptic situation over a larger area. This area around St. Louis that was used in this typing study is indicated by the large circle centered on St. Louis. The individual stations used in the typing process can be identified by referring to Figure 1.

Persistence of flow patterns is another useful factor identified by this map typing scheme. For example, in the autumn season, the most frequently persistent weather situation over the four-year period involved map Type A, which has 14 cases of a two-day persistence, four cases of a threeday persistence, two cases of a four-day persistence, and one case of a seven-day persistence. Two other map types, B and C, also have many combinations of persistence in this same autumn season grouping. It is easy to use the synoptic map typing classification to determine persistence and to predict potential stagnation periods by the judicious application of Lund's synoptic weather classification technique.

TABLE 2. SUMMARY OF SEASONAL SYNOPTIC MAP TYPES ST. LOUIS REGIONAL STUDY, 1973-1976

	Winter		Spring		Summer		Autumn	
Type	Date Of Base Map	No. Of Cases	Date Of Base Map	No. Of Cases	Date Of Base Map	No. Of Cases	Date Of Base Map	No. Of Cases
A	Feb 26, 74	59	May 15, 74	85	Jun 1, 73	86	Nov 28, 75	89
B	Jan 3, 76	58	Mar 18, 76	57	Jun 28, 75	48	Oct 15, 76	47
C	Dec 22, 76	44	Apr 4, 73	33	Jul 19, 75	44	Nov 23, 76	24
D	Jan 20, 73	31	Apr 11, 76	35	Aug 1, 73	18	Oct 26, 76	25
E	Feb 8, 75	30	May 8, 73	23	Jul 20, 75	24	Sep 5, 76	24
F	Feb 8, 76	29	Mar 21, 75	16	Jul 19, 73	15	Nov 16, 76	16
G	Feb 16, 73	21	May 6, 76	19	Jul 15, 73	21	Nov 28, 73	24
H	Dec 7, 73	16	Mar 21, 73	22	Jun 8, 76	13	Sep 3, 74	25
I	Jan 8, 74	13	Apr 3, 75	9	Jul 9, 73	5	Sep 11, 74	19
J	Dec 12, 73	10	Mar 2, 73	12	Jul 20, 73	7	Oct 2, 75	11
K	Dec 5, 75	8	Mar 22, 74	5	Jul 25, 73	10	Nov 19, 74	7
L	Jan 19, 73	7	Mar 7, 76	10	Jul 25, 75	8	Sep 4, 76	6
M			Apr 30, 76	6	Aug 20, 75	29	Nov 3, 75	6
N							Nov 10, 75	6
Misc.		35		36		39		34
Total Typed		326		332		329		329
Total Cases		361		368		367		363
Percent Typed		90%		90%		89%		91%

TABLE 3. DAILY MAP TYPE ASSIGNMENTS

Year	1973												1974											
	Winter			Spring			Summer			Fall			Winter			Spring			Summer			Fall		
Month	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Day 1	H	B	D	A	E	B	A*	A*	D*	A	A	I	O	G	I	B	E	J	G	A	O	D	D	A
2	A	H	B	J*	C	C	A	C	D	A	A	B	B	E	E	B	A	B	M	A	K	H	E	O
3	O	C	F	L	G	C	A	A	H	A	O	D	G	O	G	B	F	D	M	C	E	H*	A	B
4	O	B	J	D	C*	A	O	D	M	O	B	D	H	O	A	E	C	D	A	E	O	E	A	O
5	C	E	I	A	B	A	K	A	A	B	J	H	A	L	D	B	I	C	A	B	O	E	I	B
6	B	G	G	J	B	A	C	A	A	D	A	E	D	B	E	B	B	H	A	A	B	E	B	J
7	H*	G	E	O	G	E	A	A	A	E	A	M	B	D	G	A	O	A	A	A	L	E	J	N
8	H	E	G	D	G	E*	C	A	C	E	A	B	B	I*	F	A	O	O	F	A	A	O	O	A
9	B	B	O	D	C	E	H	I*	C	D	A	H	F	G	F	G	A	H	C	C	A	A	J	A
10	F	C	H	A	E	E	A	D	C	O	A	A	C	E	B	D	A	A	E	A	M	A	A	O
11	A	B	H	E	B	M	C	B	F	B	A	A	O	B	A	O	A	M	E	B	C	I*	I	G
12	J*	A	D	A	D	C	J	C	O	D	A	C	A	H	C	D	B	I	H	M	C	B	D	G
13	O	C	I	A	A	M	B	E	O	D	G	C	O	A	O	H	F	A	A	H	B	H	A	B
14	D	C	B	B	A	C	A	D	O	H	C	I	J	C	D	A	C	G	C	E	B	F	B	C
15	E	A	B	G	B	E	A	G*	L	D	B	B	C	F	O	M	C	A*	E	G	A	O	J	C
16	G	A	G*	C	E	C	C	B	B	D	B	A	B	C	B	C	O	B	D	B	O	F	F	A
17	D	A	H	I	A	O	A	M	A	B	F	A	L	D	A	A	B	A	C	A	O	G	H	N
18	D	C	A	A	A	B	L	A	A	J	A	O	J	E	K	K	A	A	A	C	O	F	D	A
19	E	L*	C	D	A	G	K	F*	O	I	O	A	O	D	F	D	A	A	C	I	A	L	D	K*
20	B	D*	F	D	A	A	K	J*	D	E	E	A	O	C	D	G	A	A	C	B	M	B	E	G
21	A	J	B	H*	B	A	E	J	B	A	A	C	F	L	I	E	B	O	I	O	L	H	A	O
22	A	C	C	A	B	O	H	B	M	I	A	M	A	B	B	K*	C	O	G	O	O	E	I	A
23	D	C	F	A	O	O	C	M	J	A	A	A	I	O	I	G	L	K	G	B	G	A	A	K
24	D	F	D	J	D	O	M	A	A	A	F	O	E	O	B	H	H	L	G	L	B	F	C	B
25	A	O	I	G	D	A	M	K*	A	A	C	A	F	A	F	B	A	D	G	L*	M	F	B	E
26	O	O	G	O	G	A	C	K	A	M	D	A	A	C	A*	A	A	D	B	O	C	F	N	O
27	F	E	H	A	C	F	E	E	A	D	B	B	F	O	A	A	B	A	B	O	J	I	A	C
28	K	B	A	O	A	C	E	O	A	O	B	G*	A	F	C	A	B	B	A	E	O	K	A	B
29	B	F		G	A	C	F	M	A	O	O	C	B	A		O	K	F	C	D	E	G	A	D
30	E	A		D	A	E	A	O	M	O	C	L	D	A		I	C	B	C	O	C	B	A	O
31	E	D		F		B		D	A		G		B	G		A		G		F	F		X	

Type "O" is miscellaneous map type
*Primary map type
X no map type (data missing)

(continued)

TABLE 3. (continued)

Year	1975												1976											
	Winter			Spring			Summer			Fall			Winter			Spring			Summer			Fall		
Month	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Day 1	A	B	G	G	D	H	O	B	K	O	H	I	C	A	B	A	E	E	G	F	G	D	O	A
2	L	A	G	L	C	A	A	O	O	E	J*	I	D	B	O	F	B	C	G	F	G	A	E	G
3	A	C	D	I	I*	C	A	E	O	L	F	M*	O	B*	K	L	C	I	B	G	B	I	A	G
4	A	F	I	B	H	A	C	O	O	D	A	M	D	L	E	F	D	B	B	G	A	L*	M	B
5	K*	J	B	B	H	A	K	C	G	B	C	A	D	A	E	C	O	B	B	G	J	E*	B	C
6	G	A	B	A	H	A	E	E	B	J	E	A	E	K	B	E	H	G*	O	H	G	A	D	B
7	O	J	C	C	A	J	G	O	B	O	A	C	G	E	C	L*	D	D	H	C	B	A	H	B
8	E	O	E*	L	J	D	B	D	M	E	A	I	A	B	F*	D	D	O	H*	A	B	B	O	F
9	F	D	H	A	D	D	B	D	A	E	O	O	A	A	A	O	A	B	H	M	M	B	G	G
10	A	C	A	D	G	D	O	D	C	A	O	N*	E	J	C	O	B	E	A	C	M	F	A	B
11	I	B	I	J	G	O	K	D	A	B	A	F	O	F	F	A	D*	H	A	E	A	A	A	H
12	D	B	B	G	O	L	C	D	A	H	A	G	B	A	C	C	A	J	M	O	C	A	K	B
13	A	B	D	D	A	O	C	O	F	J	A	G	H	B	G	B	A	F	A	H	F	A	G	N
14	K	A	D	I	H	M	O	A	J	A	I	C	C	C	A	K	B	D	A	C	F	L	C	J
15	O	K	E	A	A	G	C	M	O	A	B	C	B	C	C	D	B	O	K	E	B	D	B*	N
16	E	O	I	H	A	H	A	A	C	E	D	A	C	B	C	I	B	C	A	E	B	D	H	F*
17	B	A	B	A	B	O	C	A	F	A	H	A	F	G	J	B	B	C	M	H	B	L	E	C
18	F	C	B	O	E	B	A	C	F	O	H	A	A	A	C	B*	B	O	E	A	B	A	E	C
19	C	E	F	E	E	B	A	C*	B	K	C	A	B	C	O	B	A	B	D	A	B	B	B	B
20	E	A	A	A	H	B	A	E*	M*	G	C	K	B	C	D	E	F	B	H	C	M	B	G	B
21	H	E	O	F*	A	B	M	O	A	O	I	G	A	B	B	L	E	H	A	I	M	B	G	G
22	O	H	E	A	A	A	A	A	M	H	A	G	C*	A	B	O	O	D	A	A	B	A	A	G
23	G	A	O	O	B	B	A	C	A	H	A	O	F	O	A	B	A	D	A	E	B	D	A	C*
24	D	A	C	E	A	A	B	D	A	H	K	B	A	D	A	B	O	D	K	G	B	E	B	C
25	O	C	C	L	H	A	B	G	O	H	J	D	B	E	C	A	G	H	A	M	M	E	H	I
26	B	L	B	A	A	C	L	O	F	A	A	O	F	B	F	O	H	O	A	C	A	B	D*	O
27	D	I	A	J	A	H	B	E	B	A	I	I	C	H	K	A	H	J	A	A	O	H	H	B
28	D	A	B	O	B	J	B*	B	A	A	B	A*	B	C	A	A	D	J	C	C	D	O	F	H
29	O	B		C	B	F	B	B	F	A	H	I	A	F	O	F	O	A	E	A	B	O	O	C
30	H	D		B	O	C	B	B	O	B	A	G	E	G		C	M*	F	D	I	M	F	G	A
31	O	E		F		C		O	H		A		B	C		E		F		G	O		H	

*indicates the base map for this season and type
"O" indicates untyped maps

In addition to determining persistence, an examination was made of the transiting patterns of charts in a season into other types to determine if there was any regular evolution from one type to another. To make this determination, a method used by Singh, et. al. (1978), in their investigation of synoptic climatology during the summer monsoon season in India, was employed. Within each season, a simple Chi Square statistic was computed to determine if observed frequencies of occurrence of one map type were greater than the frequency of occurrence expected by chance for that type. Results of the test in this study indicated that there were significant differences between observed frequencies and expected frequencies for some pairs of map types. Accordingly, the map type file could be used to determine the more probable transitions by map types based, and the result might have obvious synoptic forecasting applications.

One would normally expect more intra-seasonal transitions between types in spring and autumn. Although the Chi Square test for all seasons is not included in this study, all seasons were tested and more predictable or non-random transitions between map types occurred in autumn and spring than in the summer and winter seasons. This might be expected on the basis of the general persistence of major weather systems in summer and winter and the more rapid system developments in spring and autumn.

AIR QUALITY APPLICATION

Direct and indirect effects of synoptic weather systems on air pollution intensity have been reported for many years by air quality meteorologists, scientists and engineers. Continuing efforts are being directed to improve both simple and sophisticated mathematical air quality models for use in nationwide pollution control strategy programs. As part of this general attempt to better understand local and regional air pollution conditions, an additional objective in this study was to find relationships between synoptic map types and specific air pollution concentrations over a given time interval. In order to test the validity of this objective in the St. Louis area, data from the St. Louis RAPS/RAMS network for total suspended particles (TSP) and carbon monoxide (CO) were analyzed by synoptic map type. Pooler (1974) EPA, described the criteria, modeling, and objectives of the RAPS program in detail in his paper on the RAPS network siting requirements. The RAPS network of 25 stations was arranged in an expanding pattern of four concentric circles originating from the downtown St. Louis Arch at radial intervals of 4, 10, 20 and 40 kilometers, as shown in Figure 3.

The selection of TSP and CO concentration data to determine possible relationships with weather types was made for several reasons. First, essentially non-reactive pollutants were assumed to provide a situation uncomplicated by photochemistry and other rapid reaction systems. Second, the pollutant sources for both pollutants should be widely distributed but with different source patterns. Third, and obviously, the data should have been reported by the RAPS monitoring network. In addition both TSP and CO are important urban area and regional pollutants and a correlation between these measurements and weather types could be useful, directly, in increasing the understanding of air pollution problems in the St. Louis area.

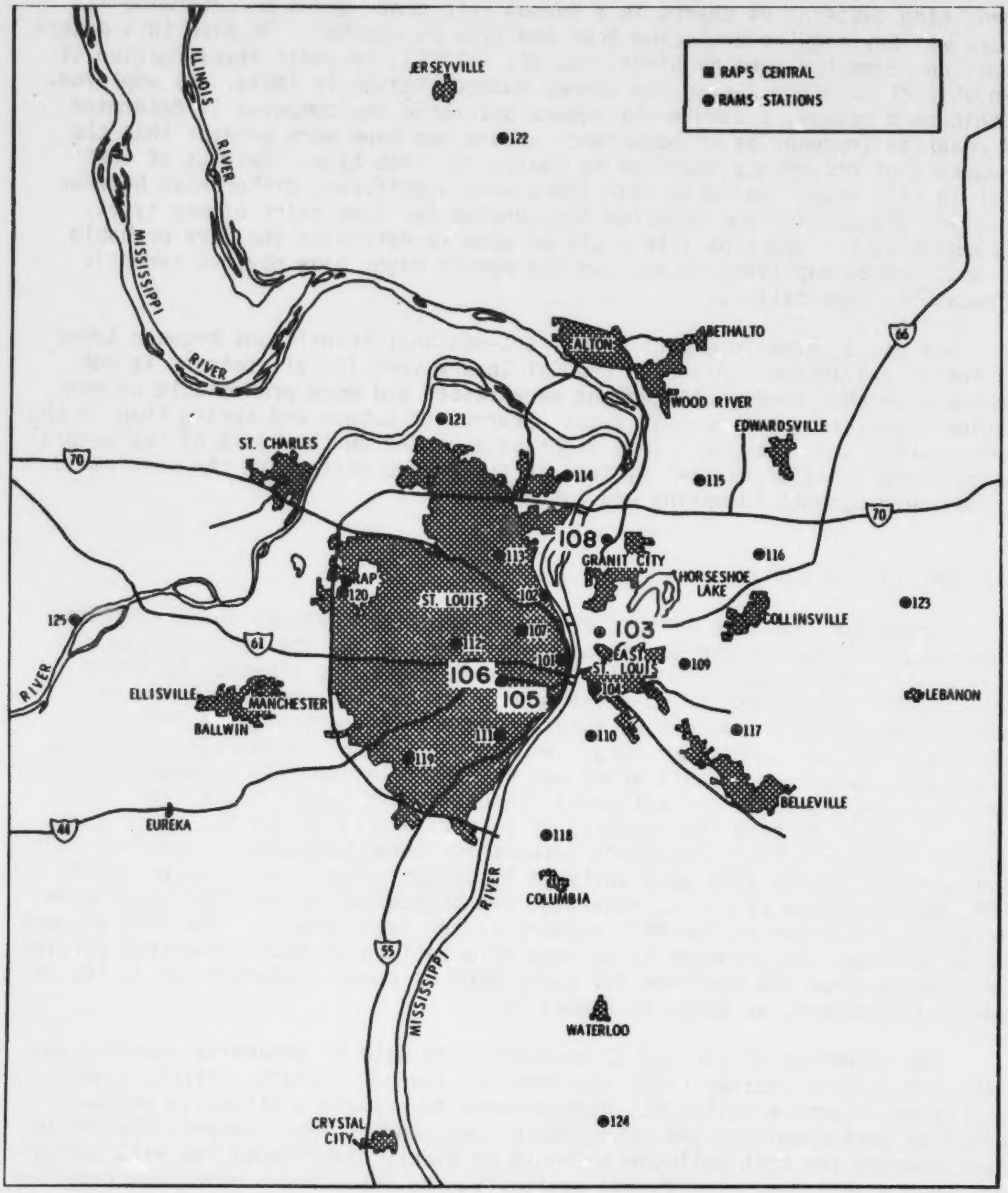

Figure 3. St. Louis Regional Air Pollution Study air monitoring network, 1975-1976.

In our study, we concluded that from the network the four centrally located sites--numbers 103, 105, 106 and 108--were the most likely to show how synoptic weather might influence TSP and CO pollution concentrations. These four RAMS stations provide an indication of the average levels of TSP and CO across the central part of the St. Louis commercial and industrial area. It was expected that changes in synoptic weather, as indicated by weather types, would give the optimum relationship between the synoptic influence in this part of the city and the levels of concentration of these pollutants.

Air Quality Data Analysis

In the RAPS program, air quality data were collected on both TSP and CO for 22 months during the period from January 1975 through December 1976. Sampling for TSP was done every third day and was the usual 24-hour average Hi Vol sample collection. Sampling for CO was the usual continuous nondispersive IR recording instrumental observation. This sampling pattern resulted in an approximate three-fold difference in the total number of daily average values obtained between TSP and CO. One factor that influenced the selection of station data for analysis was the fact that not all air quality measurements were taken at all of the RAMS/RAPS stations. Thus some type of preliminary data screening and station selection was necessary to determine a suitable procedure for correlating St. Louis air quality with the synoptic weather types. Several combinations of stations were tried, including network averages, and it was decided to use an average of the four central RAPS/RAMS network stations previously mentioned, numbers 103, 105, 106 and 108, see Figure 3.

The next step was to relate air quality concentrations for TSP and CO by date with the seasonal map type for the same date. After seasonal geometric means, variances, standard deviations, and coefficients of variance had been computed for averages of the four selected RAMS stations 103, 105, 106 and 108, the data were analyzed statistically. The geometric mean was chosen to insure greater sensitivity throughout the statistical population. Indications of significance between map types was sought. The first test performed on the data was an analysis of variance and an F test. When the results of this procedure indicated that there were differences between map types within each season, a more powerful statistical procedure, the Duncan's new multiple range test (Steel and Torrie, 1960) was employed to determine more conclusively air quality differences between pairs of synoptic types. The WSU computer systems, which incorporated the Statistical Analysis System (SAS) algorithm, was applied to these data.

Total Suspended Particle Comparisons

The tabular ranking of seasonal maps by high to low TSP concentrations, map types, number of cases, and average concentration values measured in $\mu g/m^3$, for RAMS stations 103, 105, 106 and 108, is given in Table 4. It should be noted that the National Ambient Air Quality Standard for TSP is 260 $\mu g/m^3$ averaged over 24 hours. None of the averaged St. Louis data

TABLE 4. SEASONAL MAP TYPES RANKED BY TOTAL SUSPENDED PARTICLE CONCENTRATIONS AVERAGED FOR STATIONS 103, 105, 106, 108.

		Winter			Spring			Summer			Fall	
Rank	Type	N†	TSP µg/m^3	Type*	N	TSP µg/m^3	Type**	N	TSP µg/m^3	Type***	N	TSP µg/m^3
1	L	3	98.3	G	3	94.2	M	3	161.0	M	12	114.9
2	E	10	97.0	K	12	90.9	J	5	116.7	A	36	103.9
3	F	9	97.0	C	21	90.0	B	17	90.6	F	9	103.6
4	A	27	90.0	I	3	77.0	H	15	86.5	C	21	102.9
5	B	18	86.5	F	9	68.6	C	7	86.0	E	14	85.5
6	J	5	81.5	A	14	63.2	D	8	84.9	D	8	82.2
7	I	18	80.3	J	2	58.3	G	5	84.5	B	25	81.1
8	D	6	68.7	E	15	56.8	A	22	82.7	H	9	79.4
9	C	15	67.8	B	20	55.9	E	8	75.5	K	5	72.8
10	K	8	67.6	D	6	52.6	F	7	63.6	G	9	59.4
11	H	14	64.5	L	4	47.4	L	6	62.7	L	5	52.4
12	G	12	61.9				I	8	40.4			

*Type H, no data
**Type K, no data
***Types I and J, no data
†N indicates number of station average values

approached this level. As shown by the seasonal columns in Table 4, each classification has, at least qualitatively, three concentration categories of map types. There is a group at the upper end of the distribution, one at the low concentration end, and a group that is intermediate between these two. For example, there are four autumn map types with concentrations >100 μg/m^3, five map types with concentrations between 60 and 100 μg/m^3, and two map types with concentrations <60 μg/m^3. In order to examine this phenomenon more clearly, each season was reviewed separately by map type and TSP concentration and with reference to the data in Table 4.

(A) Winter - an examination of the five winter weather types L, E, F, A, and B with TSP concentration levels which exceed 85 μg/m^3 indicated similar wind flow patterns over the St. Louis area, predominantly from the western quadrants. Additionally, map types A, F, and E, with the highest concentration levels, that is TSP concentrations of 85 μg/m^3 or higher, were significantly different from the two map types H and G with the lowest concentration levels, i.e., TSP concentrations of 65 μg/m^3 and below. In the winter group of map types with concentrations between 75 μg/m^3 and 85 μg/m^3, there was no pattern or much variation of actual TSP concentrations. This was substantiated by the statistical non-significant results of the Duncan's test comparing map types K, C, D, I, and J.

From a meteorological synoptic standpoint winter weather can include both stable, stagnant weather situations that favor pollutant accumulation and storm situations that provide excellent pollutant dilution. With regard to TSP concentrations precipitation and wet ground would tend to reduce ambient concentrations and surface sources of fugitive dust.

(B) Spring - This season is typically unstable with rapidly moving, active weather systems. The map types, with their overall lower TSP concentrations when compared generally to the other seasons, support this contention. Despite the seasonal tendency for dynamic instability, map types G, K, and C had concentrations of 90 μg/m^3 or higher and two in this group with the largest number of cases, C and K, were significantly different from types A, B, D, and E, whose concentrations were below 65 μg/m^3. The weather patterns of the map types with the higher concentrations, e.g., 90 μg/m^3 or higher, had wind flow from the west, southwest and northwest sectors. The remaining weather map types had active synoptic situations where frontal activity was either just approaching or just receding from the St. Louis area, within the previous six-hour period.

(C) Summer - Traditionally, air pollution episodes are associated with strongly modified or quasi-stationary systems of high pressure. When this situation becomes widespread, air pollution episodes similar to the ones described by Lynn, et al. (1964) and a number of other investigators can occur. Accumulation of particulate pollutants leading to wide spread visible haze has been observed to be highest generally in the western or southwestern sector of anticyclones moving slowly across the US midwest and east coast from northwest to southeast, particularly if there is a frontal system or trough behind the high that brings in upper air clouds which tend to limit mixing and dispersion of pollutants. This western sector of these modified continental polar anticyclones is frequently identified as the "backside" of the High. Map type M (summer) is an example of this type of phenomenon where St. Louis is on the westside of an anticyclone centered in West Virginia and shows a high cloud layer, at a reported 25,000 feet on the August 20, 1975 base map, due to a trailing front to the northwest. The average TSP concentration of 161 $\mu g/m^3$ associated with this map type exceeds the 150 $\mu g/m^3$ secondary National Air Quality Standard for a 24-hour maximum concentration.

Although only two map types, J and M, corresponded to daily TSP concentrations that were >115 $\mu g/m^3$, they both were significantly different than map types F, L, and I which had the lowest concentrations in this season, i.e., <65 $\mu g/m^3$.

(D) Autumn - Although this season is normally transitional with frequent unstable weather conditions, stable conditions are also frequent and average pollution concentrations were generally higher than in the spring season.

Four map types, M, A, F, and C, had TSP concentrations of over 100 $\mu g/m^3$, and they were significantly different than map types G and L associated with TSP concentrations of <60 $\mu g/m^3$, the lowest concentra tions in this seasonal grouping. Wind flow for these four high concentration map types, which were dominated by strong high pressure cells, ranged from 4 to 10 kts, while those with the lowest concentrations had velocities from 12 to 16 kts, generally characteristic of good dispersion characteristics.

As a result of these analyses, it is has been concluded that the various map classifications by the Lund (1963) statistical technique, used in conjunction with related TSP concentrations, generally identify synoptic weather patterns with specific pollution concentrations that may be classed as high, medium and low levels.

Table 5 lists the results of comparing the average concentrations by map type and indicates whether or not the differences between TSP concentrations for pairs of map types were statistically significant (S) or non-significant (N). Map types in Table 5 having statistical significance for TSP concentrations, designated S, are generally similar to those map types identified qualitatively by ranking in Table 4. Subsequent discussion examines the situation in more detail. In the winter group of Table 4 map types A, E, and F showed a significant difference from map types G and H, which correlated with the winter group in Table 4. However, map type L, which has only three cases, did not show statistical significance, although its average concentration level was high. This is an example of a common statistical problem in dealing with small sample numbers and significance testing. In the spring season, map types C and K were significantly different from map types A, B, D, and E which correlated with the ranking by concentration of these map types. Map type G, with the highest concentration and lowest number of cases, again did not manifest statistical significance in this group. In the summer group map types J and M were significantly different from map types F, L, and I, which agreed

TABLE 5. RESULTS OF STATISTICAL SIGNIFICANCE TESTS FOR TSP CONCENTRATION DIFFERENCES BETWEEN MAP TYPE PAIRS

Statistical Significance Noted by S, Non-significance by N

WINTER

A	B	C	D	E	F	G	H	I	J	K	L
A	N	N	N	N	N	S	S	N	N	N	N
B		N	N	N	N	N	N	N	N	N	N
C			N	N	N	N	N	N	N	N	N
D				N	N	N	N	N	N	N	N
E					N	S	S	N	N	N	N
F						S	S	N	N	N	N
G							N	N	N	N	N
H								N	N	N	N
I									N	N	N
J										N	N

SPRING*

A	B	C	D	E	F	G	I	H	K	L
A	N	S	N	N	N	N	N	N	N	N
B		S	N	N	N	N	N	N	S	N
C			S	S	N	N	N	N	N	S
D				N	N	N	N	N	S	N
E					N	N	N	N	S	N
F						N	N	N	N	N
G							N	N	N	N
I								N	N	N
J									N	N
K										S

SUMMER**

A	B	C	D	E	F	G	H	I	J	L	M
A	N	N	N	N	N	N	N	S	N	N	S
B		N	N	N	N	N	N	S	N	N	S
C			N	N	N	N	N	S	N	N	N
D				N	N	N	N	S	N	N	S
E					N	N	N	S	N	N	S
F						N	N	N	S	N	S
G							N	S	N	N	N
H								S	N	N	S
I									S	N	S
J										S	S
L											S

AUTUMN***

A	B	C	D	E	F	G	H	K	L	M
A	S	N	N	N	N	S	N	N	S	S
B		N	N	N	N	N	N	N	N	S
C			N	N	N	S	N	N	S	N
D				N	N	N	N	N	N	N
E					N	N	N	N	N	N
F						S	N	N	S	N
G							N	N	N	S
H								N	N	N
K									N	N
L										S

* Map type H missing, no data
** Map types K and M missing, no data
***Map types I, J, M, and N missing, no data

with the ranking by concentration of these map types. However, in this instance, map type M, with the lowest number of cases, did indicate statistical significance. Finally, in the autumn season, map types M, A, F, and C were significantly different from map types G and L which also corresponded to the ranking by concentration for this group of maps. The number of cases in this autumn group was fairly high, i.e., nine or more.

In this study, Duncan's test proved to be a valid procedure for determining the statistical significance between map type pairs and their corresponding levels of TSP. Not unexpectedly, it appears that when the number of cases involved in the statistical computations was much less than 10, it was usually not possible to demonstrate significance. Although the one case in the summer group involving map type M was an exception to this pattern, the especially high concentration average of 161.0 $\mu g/m^3$ was probably a contributing factor.

Carbon Monoxide

Carbon monoxide concentrations and weather type relationships were also examined qualitatively by concentration ranking and statistically using the Duncan's multiple-range test. Two methods of data averaging, a total daily basis and by peak traffic periods, were used in this phase of the study.

First, seasonal tabulations of simple daily averages from the four central area RAMS stations (103, 105, 106 and 108) were sorted according to map seasonal type. The map types were then ranked according to average CO concentrations. The results are shown in Table 6. The indicated number of observations, N, is the number of daily average station values for CO. At least 13 hourly averages from a given station were considered necessary to produce a daily average value from that station. In a second data file the CO data were averaged to include observations made during the morning (0600 to 1000) and evening (1600 to 2000) traffic periods. This would tend to identify maximum local concentration situations. Neither of these two groupings of the CO data, the 24-hour daily average or the morning plus evening peak traffic average, correspond to the specifications of the National Ambient Air Quality Standards for CO. These are 9 ppm for a 8-hour average and 35 ppm for a 1-hour average, neither to be exceeded more than once per year.

The daily average CO concentrations shown in Table 6 indicate variations by factors of two to three between maximum and minimum 24-hour average values by map types, intra-seasonally. As with the TSP values, the differences between the seasonal map types having the highest and lowest concentrations tested statistically significant at the 5% level. A comparison of the rankings of map type by pollutant concentration shown for TSP in Table 4 and for CO in Table 6 indicates that there is generally a different order of map types for each of these two pollutants. Except for the map types discussed below, there is little similarity between the order of intraseasonal ranking between map types for TSP and CO when the higher and lower concentration categories are considered. For example, in the autumn when TSP values were generally higher than in the other seasons, map types M, A, and F had the highest average TSP concentrations. For CO concentrations, these same map types ranked fifth, seventh, and second, with only type F in both lists. The three highest

TABLE 6. SEASONAL MAP TYPES RANKED BY CARBON MONOXIDE CONCENTRATIONS AVERAGED FOR STATIONS 103, 105, 106, and 108

	Winter			Spring			Summer			Autumn		
Rank	Type	N	Conc (ppm)	Type	N	Conc (ppm)	Type	N	Conc (ppm)	Type	N	Conc (ppm)
1	N	8	1.081	I	14	2.260	M	7	.768	H	29	.572
2	F	25	1.050	J	13	1.277	K	4	.542	F	30	.509
3	J	18	.823	F	33	1.045	A	107	.471	L	8	.477
4	C	29	.674	L	9	.962	J	26	.447	B	105	.459
5	E	37	.636	E	51	.960	F	30	.416	M	49	.436
6	L	14	.617	H	20	.934	I	19	.408	C	66	.388
7	A	139	.556	D	42	.893	E	39	.397	A	136	.383
8	K	8	.505	A	98	.838	D	68	.391	K	11	.376
9	D	28	.490	G	25	.772	B	106	.382	J	4	.360
10	M	10	.472	C	79	.736	H	53	.370	G	45	.357
11	B	86	.449	B	99	.718	L	24	.341	D	30	.339
12	G	53	.419	K	19	.705	C	49	.320	E	36	.320
13	H	52	.324				G	20	.309	I	7	.213
14	I	35	.300									

*n = number of daily station averages where a minimum of 13 hourly averages are required to calculate a daily average.

concentration CO maps in the autumn were H, F, and L; for TSP these types ranked eighth, third, and eleventh. The other seasons show a similar lack of close correlation between the concentration ranking of these two pollutants and given map types. An explanation for this situation is not readily apparent, and this is an area for research in future investigations.

In the compilation of CO concentration on the basis of averages over the two, four-hour peak traffic periods for our 4-station data set, there seemed to be a strong bias toward the winter season and toward some relatively high individual concentration levels within some of the wintertime synoptic weather situations. There were, in all, seven map types with relatively high traffic period CO. Six of these were winter map types, A, C, I, J, K, and L, with concentrations ranging from a low of 6.4 ppm to a high of 35.2 ppm. There was one summer map type, M, which had a relatively high concentration of 11.3 ppm. These seven were the only types during the RAPS period of 1975 and 1976 which could be classed as potentially significant in terms of CO air quality standard, 9 ppb for a continuous eight-hour average. The winter season appears to have the most frequently occurring weather that is conducive to occasional local carbon monoxide buildup. There was one characteristic that was common to five of the six winter map types: a southerly wind flow with a moderate speed of 10 to 12 mph. The one winter type that differed from this pattern, L (W), had a northwesterly flow at about 10 mph. During the summer season, the one significant map type, M(S), had a southerly flow. Generally, wind flows from the south resulted in higher concentration levels of pollutants in most instances.

The application of the weather typing concept to include the local, peak traffic situations does not appear to be productive. It is likely that local- or short-term weather factors, such as wintertime urban stability conditions, might be difficult to categorize on the basis of larger scale weather systems. Additionally, local effects in the vicinity of the sampling sites due to traffic peaks, day of the week, traffic changes, and industrial operations might be creating enough interference to mask detectable synoptic weather influences Some station location and sampling problems that were encountered in the RAPS CO monitoring program have been examined by McClenny and Chaney (1978).

An analysis for statistical significance by the Duncan's test similar to that discussed above for TSP was performed for the daily average carbon monoxide concentrations. The results are tabulated in Table 7 where "S" indicates a statistically significant difference between the map type pair and, "N" indicates non-significance. In the winter season, the two highest CO concentration map types, N and F, were significantly different from the two lowest CO concentration map types H and I. Both the high and low concentration categories were significantly different from the intermediate map types B and D. The third highest winter type, J, showed a significant difference from map types B, G, H and I, but not from D. The number of cases that were available in each category was important in the statistical outcome of the Duncan's test in the CO comparison as it was in the TSP analysis. This is particularly apparent in the summer map types M and K with 7 and 4 cases, respectively, where only minimum significance could be established.

TABLE 7. RESULTS OF STATISTICAL SIGNIFICANCE TESTS FOR CO CONCENTRATION DIFFERENCES BETWEEN MAP TYPE PAIRS

Statistical Significance Noted by S, Non-significance by N

WINTER

A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	N	N	N	N	S	N	S	S	N	N	N	N	N
B		S	N	N	S	N	S	S	S	N	N	N	S
C			N	N	N	S	S	S	N	N	N	N	N
D				N	S	N	N	S	N	N	N	N	S
E					S	S	S	S	N	N	N	N	N
F						S	S	S	N	N	N	S	N
G							N	N	S	N	N	N	S
H								N	S	N	S	N	S
I									S	N	S	N	S
K										N	N	N	N
L											N	N	N
M													N

SPRING

A	B	C	D	E	F	G	H	I	J	K	L
A	N	N	N	N	N	N	N	S	N	N	N
B		N	N	N	N	N	N	S	S	N	N
C			N	N	N	N	N	S	S	N	N
D				N	N	N	N	S	N	N	N
E					N	N	N	S	N	N	N
F						N	N	S	N	N	N
G							N	S	N	N	N
H								S	N	N	N
I									S	S	S
J										N	N
K											N

SUMMER

A	B	C	D	E	F	G	H	I	J	K	L	M
A	N	S	N	N	N	N	N	N	N	N	N	N
B		N	N	N	N	N	N	N	N	N	N	N
C			N	N	N	N	N	N	N	N	N	S
D				N	N	N	N	N	N	N	N	N
E					N	N	N	N	N	N	N	N
F						N	N	N	N	N	N	N
G							N	N	N	N	N	S
H								N	N	N	N	N
I									N	N	N	N
J										N	N	N
K											N	N
L												N

AUTUMN

A	B	C	D	E	F	G	H	I	J	K	L
A	N	N	N	N	N	N	S	N	N	N	N
B		N	N	S	N	N	N	S	N	N	N
C			N	N	N	N	N	N	N	N	N
D				N	N	N	S	N	N	N	N
E					N	N	S	N	N	N	N
F						N	N	S	N	N	N
G							S	N	N	N	N
H								S	N	N	N
I									N	N	N
J										N	N
K											N

SECTION 3

SUMMARY AND CONCLUSIONS

The statistical map classification process developed by Lund (1963) was used to compile a comprehensive set of synoptic weather map types for the St. Louis, Missouri, region on a seasonal basis for the four-year period 1973-1976. This covered the 1975-76 operational period of the EPA Regional Air Pollution Study centered in St. Louis. The map types were used along with average TSP and CO concentration data from the central area of the St. Louis RAPS network to assess average TSP and CO pollutant concentrations on the basis of seasonal synoptic weather types.

Statistical methods including analysis of variance and Duncan's multiple-range test were used to test the differences between the pollutant means calculated for the various seasonal synoptic weather types. The analysis concentrated on conditions measured at four central St. Louis RAPS stations, numbers 103, 105, 106, and 108.

As would be expected from considerable prior information synoptic scale weather, when expressed as weather types, influences the pollutant concentrations of both TSP and CO, sometimes to a significant degree. For example, the TSP map types may be easily categorized into three pollutant concentration categories of high, medium, and low relative to the seasonal average. One summer map classification, type M, with an average 4-station concentration of 161 $\mu g/m^3$ can be compared to the "classical" summer anticyclonic model which is noted for its high levels of pollutant concentrations. The general wind directions in the St. Louis area as related to the synoptic situations, particularly in the spring season, also appear to play an important role in the observed concentrations of pollution.

The differences between carbon monoxide concentrations for selected map types were also significant. However, there was a different set of map types associated with high concentrations of carbon monoxide than with high TSP levels. Future research should investigate this aspect.

Although there have been difficulties mentioned in this report with regard to the statistical treatment of the data file, the results of this investigation comparing selected weather classifications with air quality should provide a reasonable basis for evaluating the RAPS data and for further research. The tabulation of daily weather by an objective weather typing technique should have applications to other research in the modeling of air pollution conditions in the St. Louis area. This research program is continuing with the particular goal of developing, if possible, objective weather typing systems that are more closely related to air pollutant concentration patterns than the 1963 sea level pressure pattern correlation system of Lund used in this report.

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Appendix

Base Maps for Synoptic Weather Map Types

Section 1 Winter

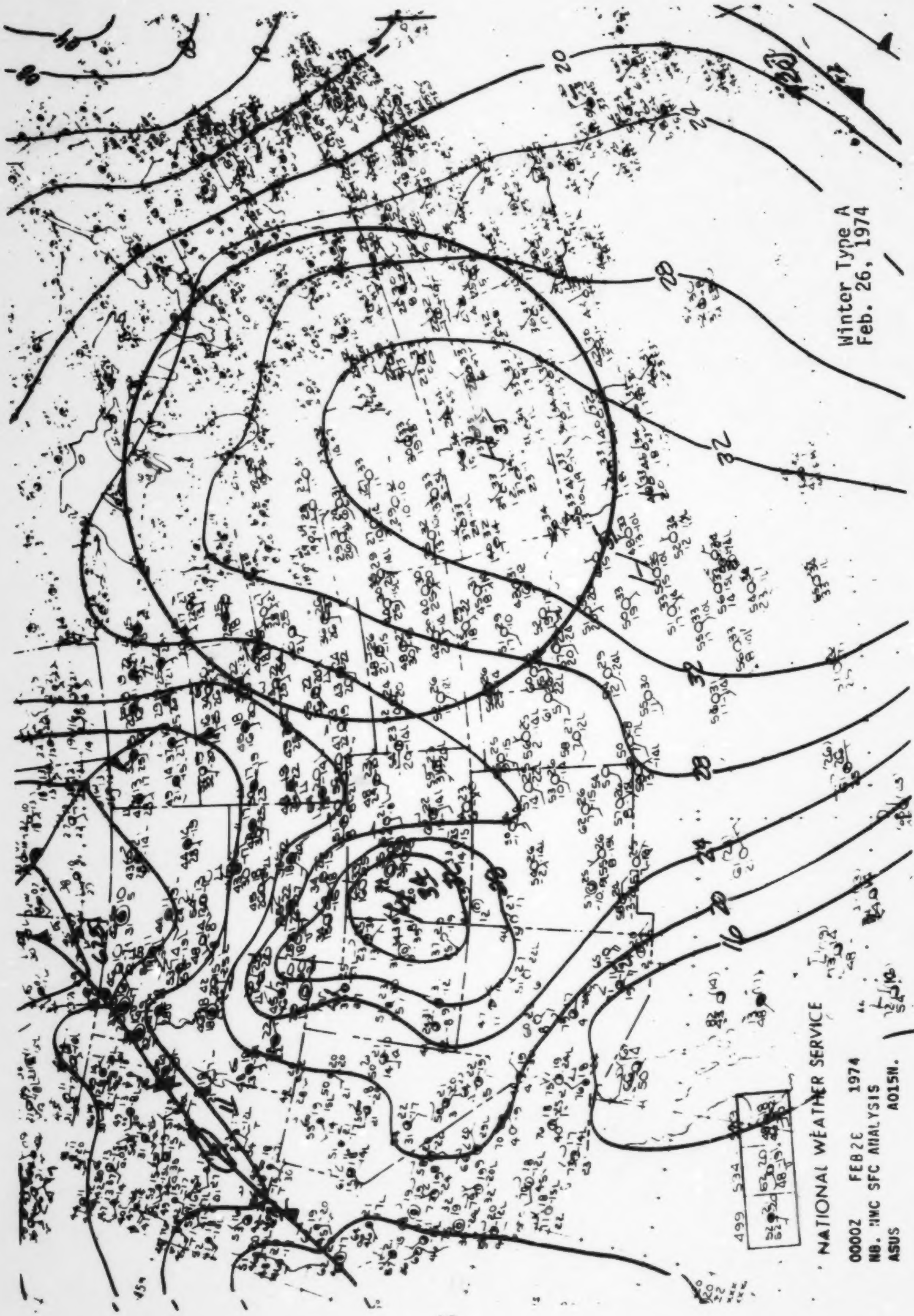
Section 2 Spring

Section 3 Summer

Section 4 Autumn

Appendix A - Section 1

Winter Map Types



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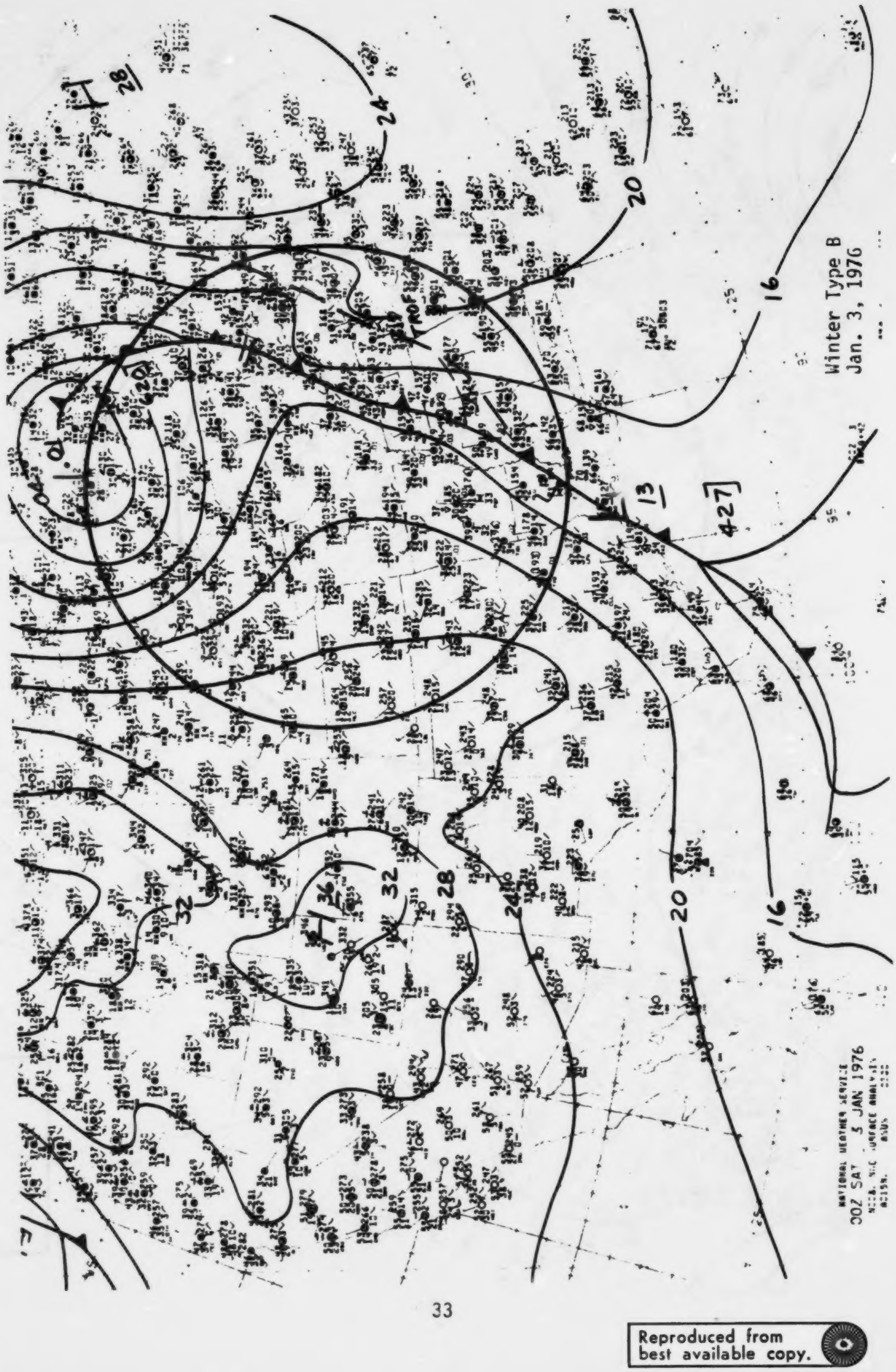

Winter Type B
Jan. 3, 1976

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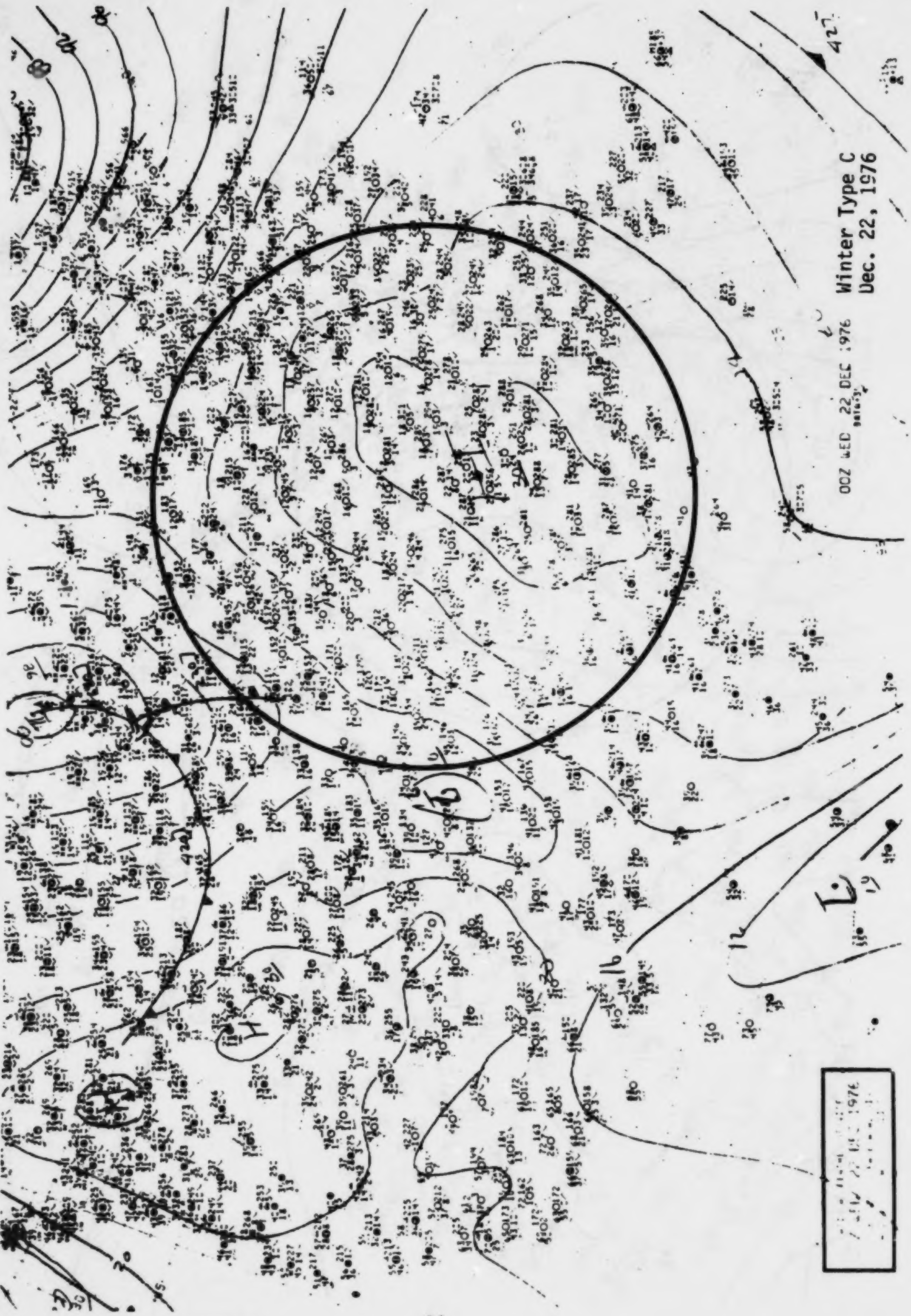

Winter Type C
Dec. 22, 1976

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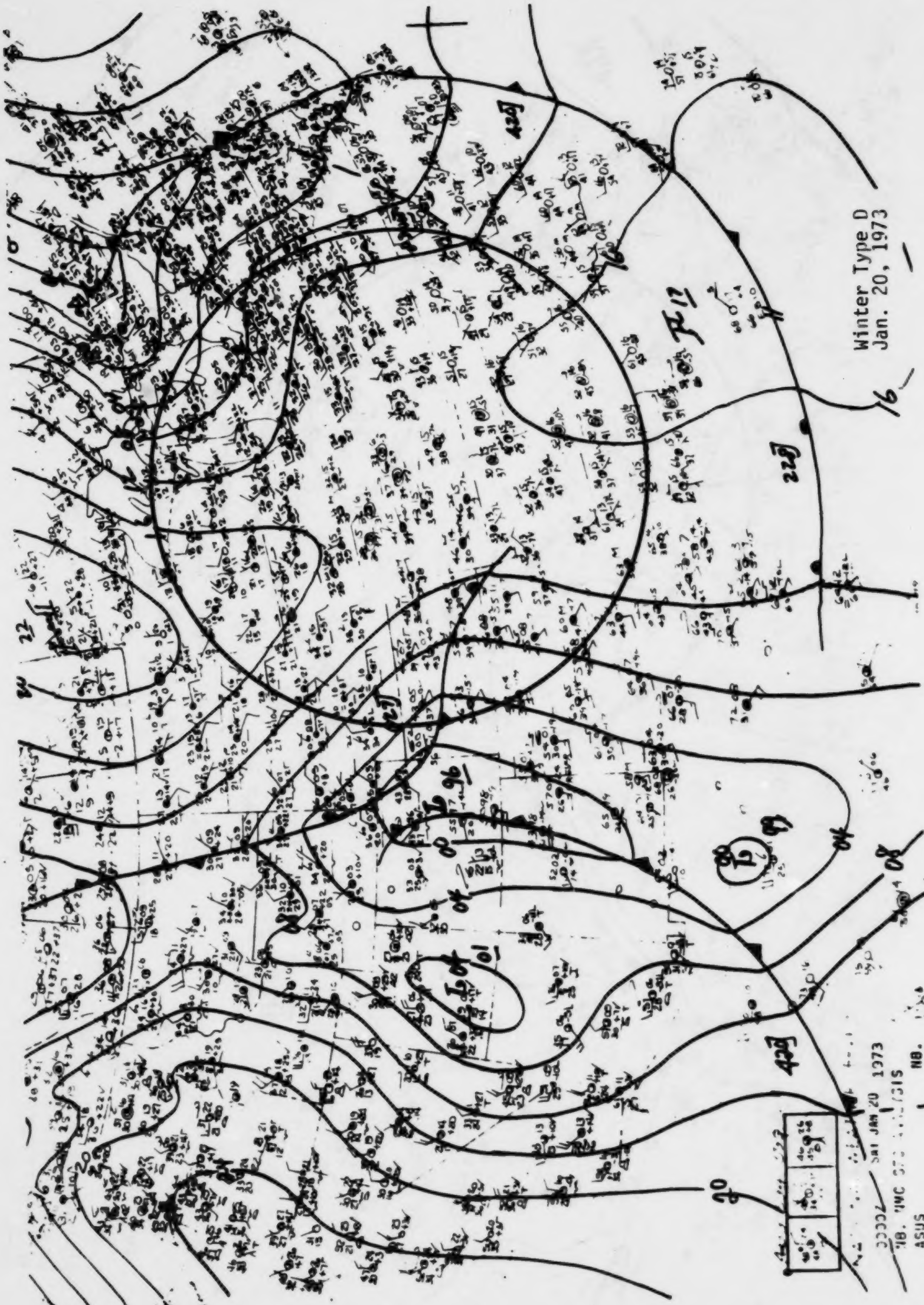

Winter Type D
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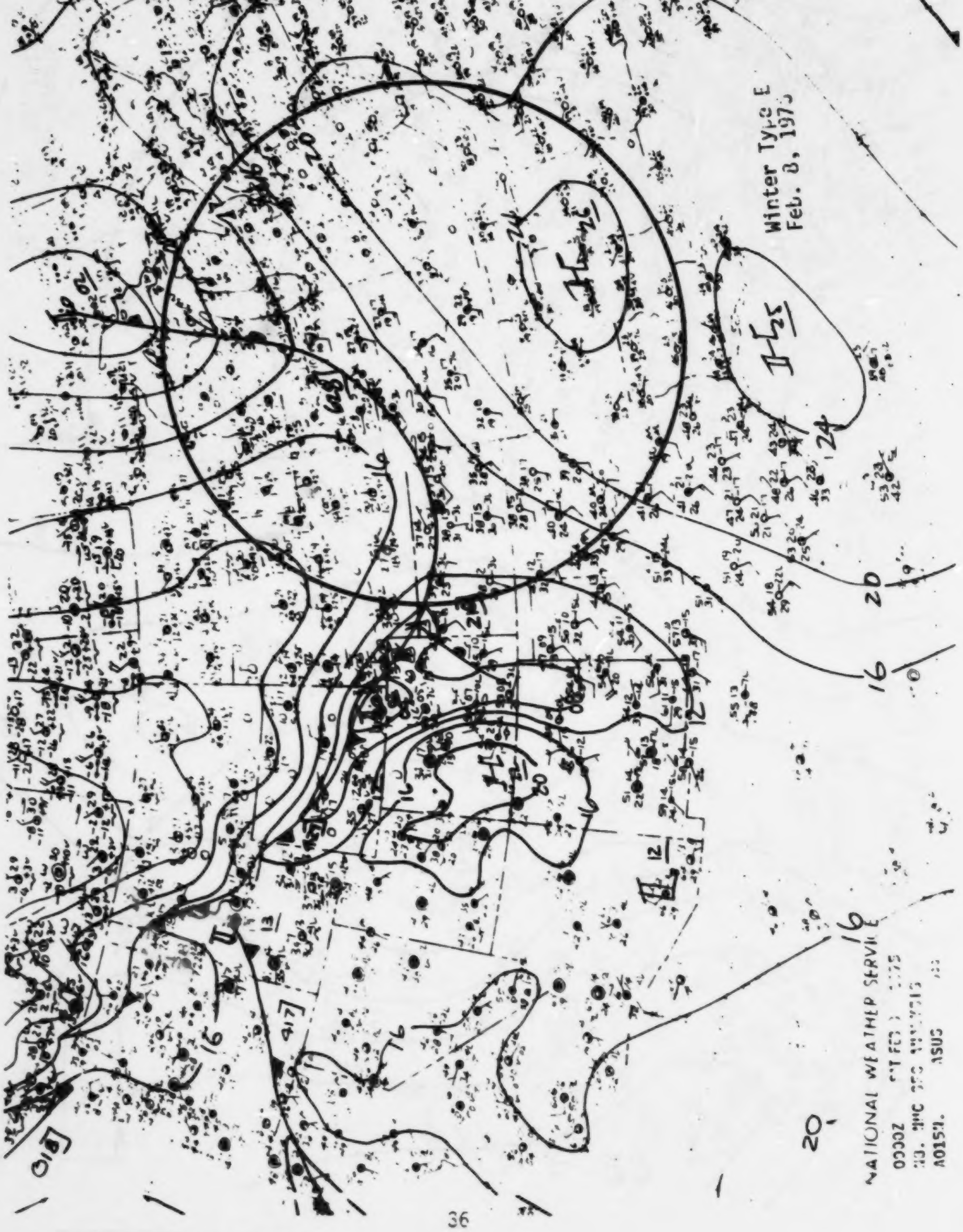

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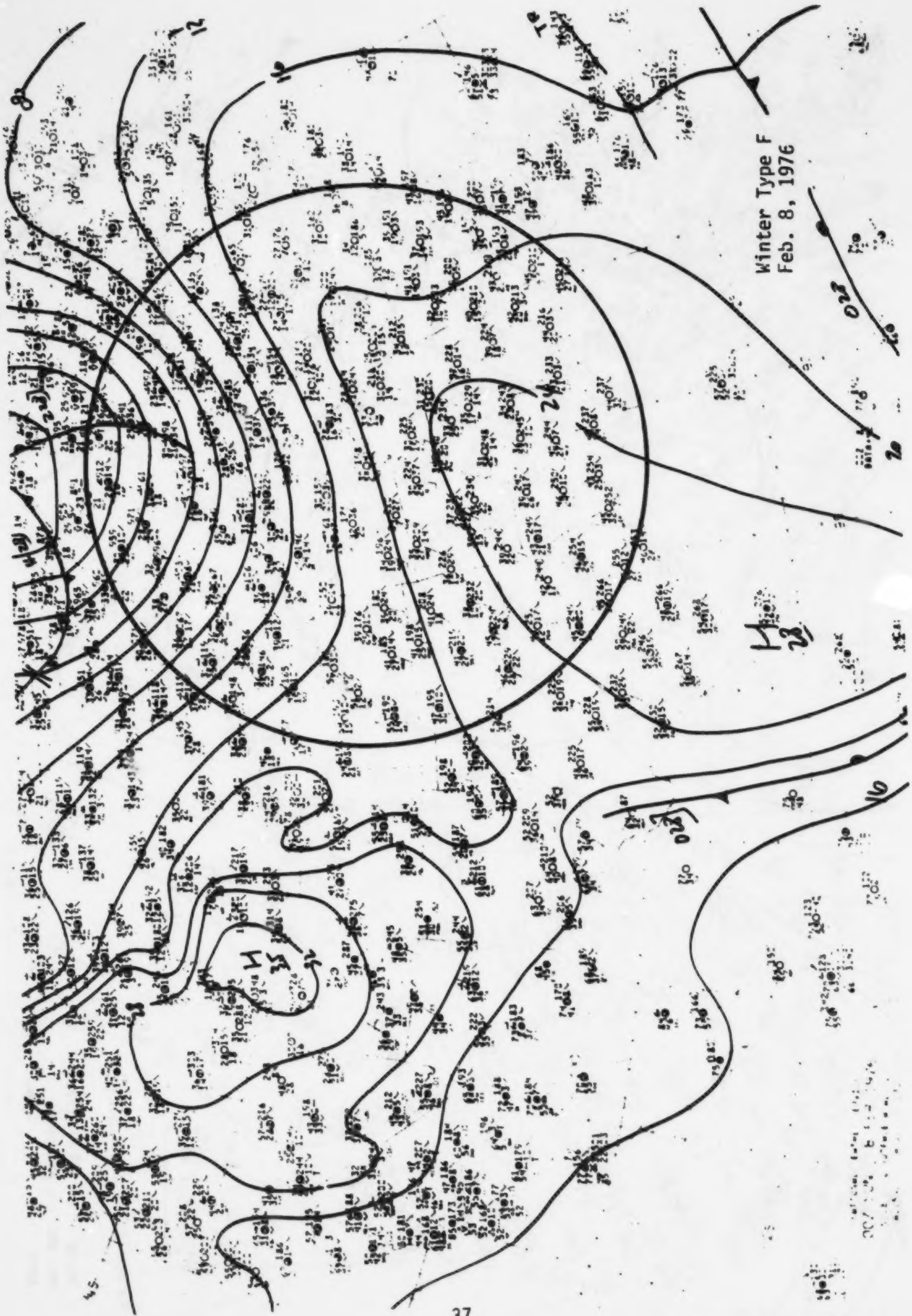

Winter Type F
Feb. 8, 1976

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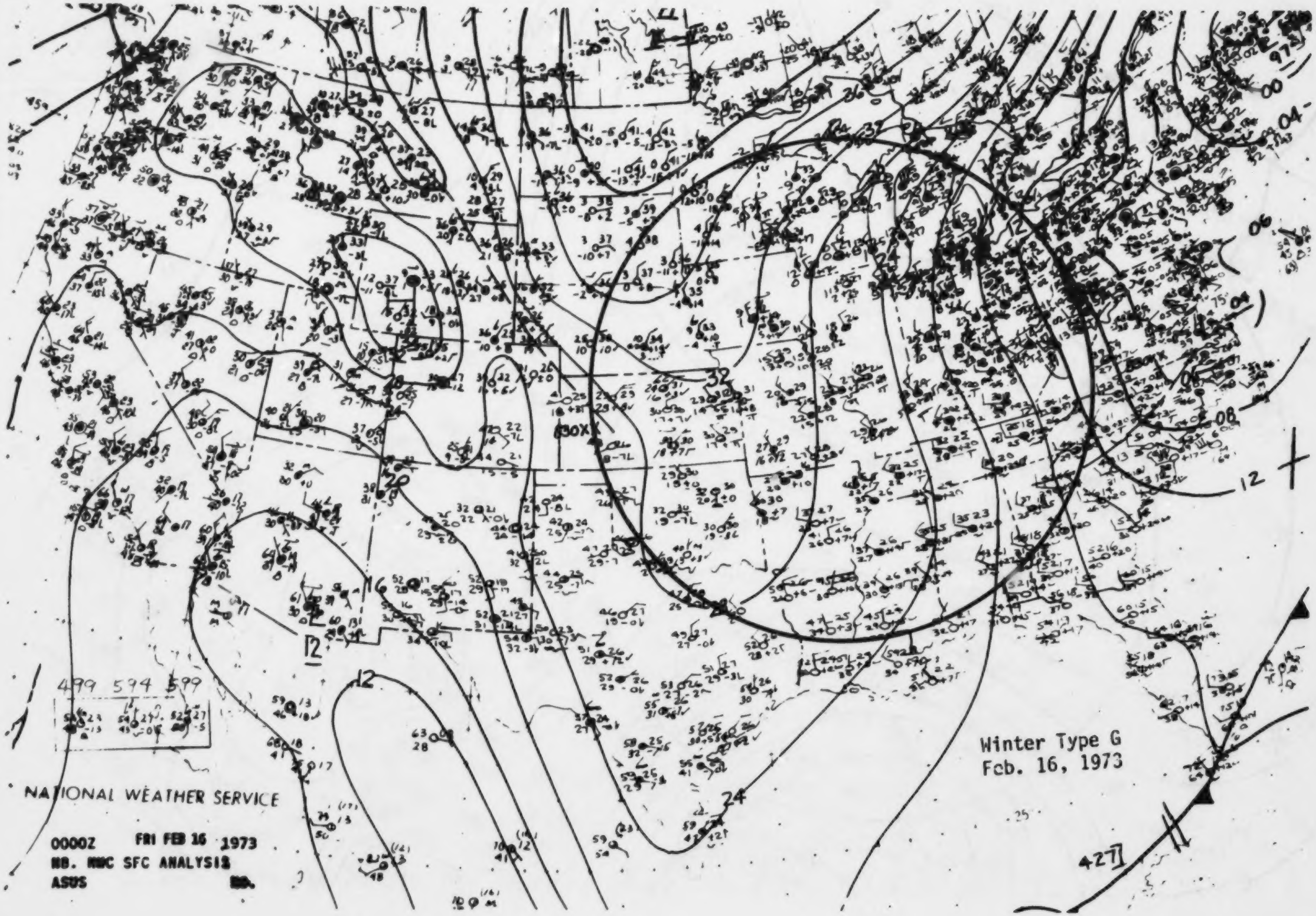

Winter Type G
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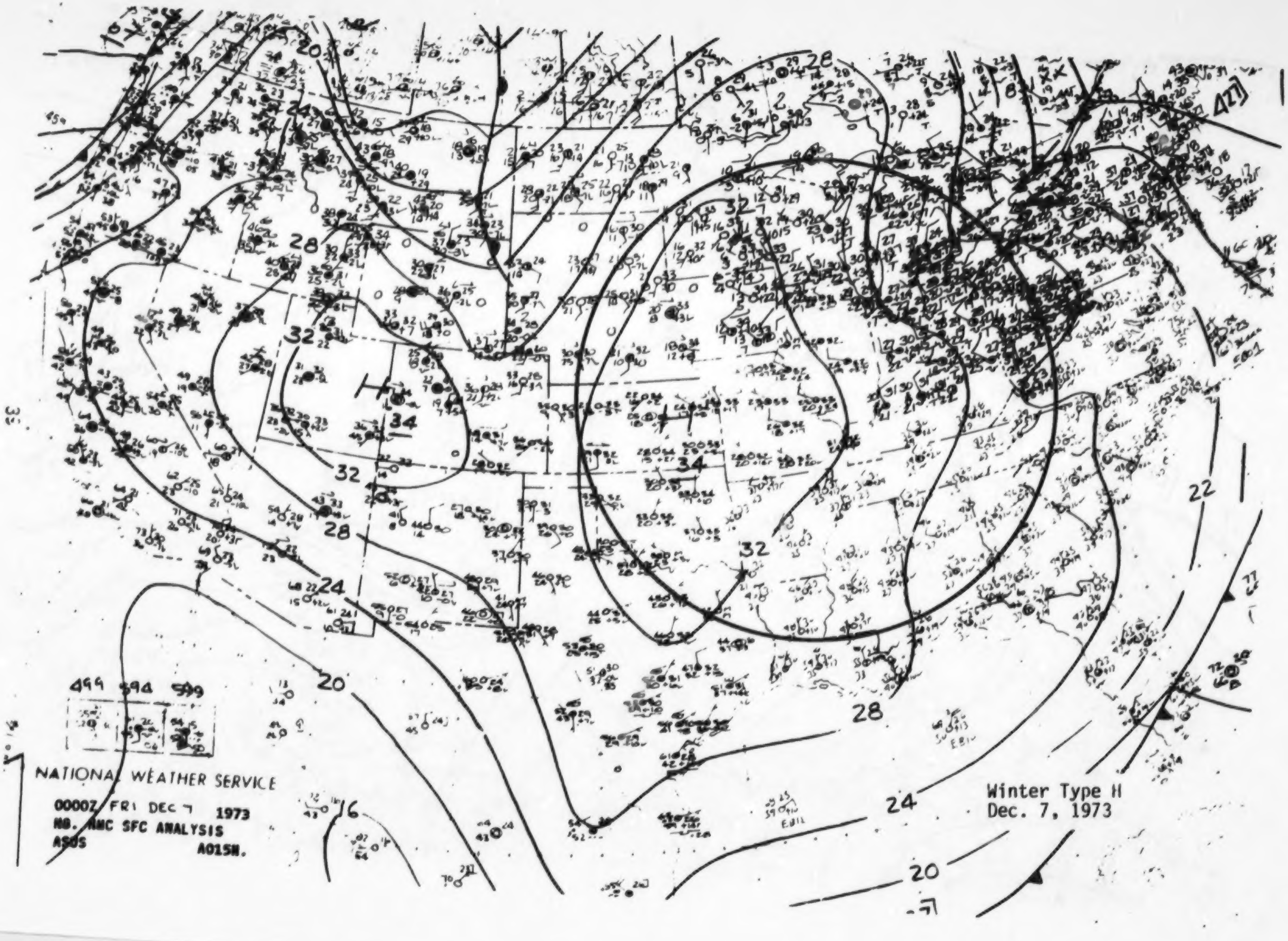

Winter Type II
Dec. 7, 1973

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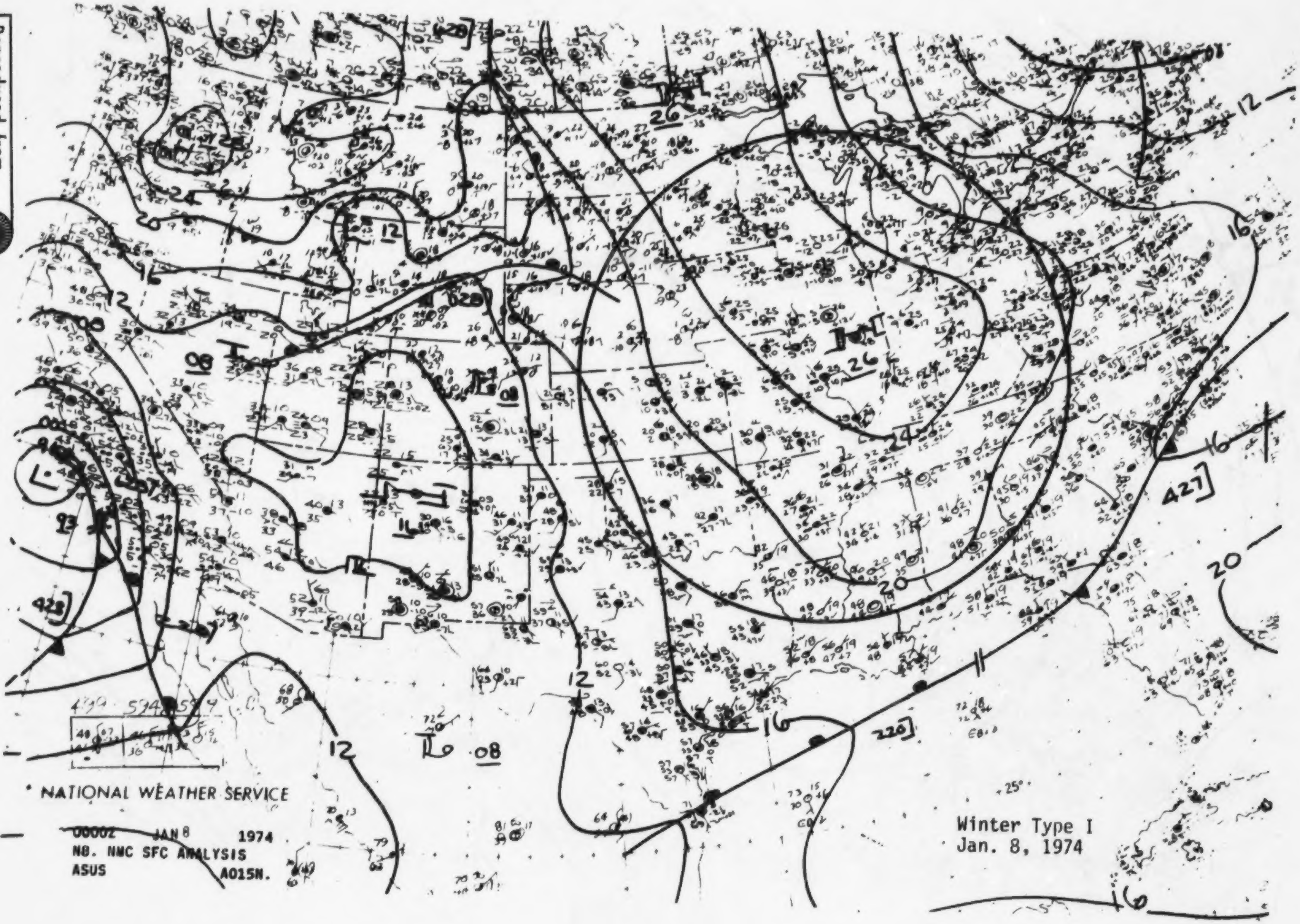
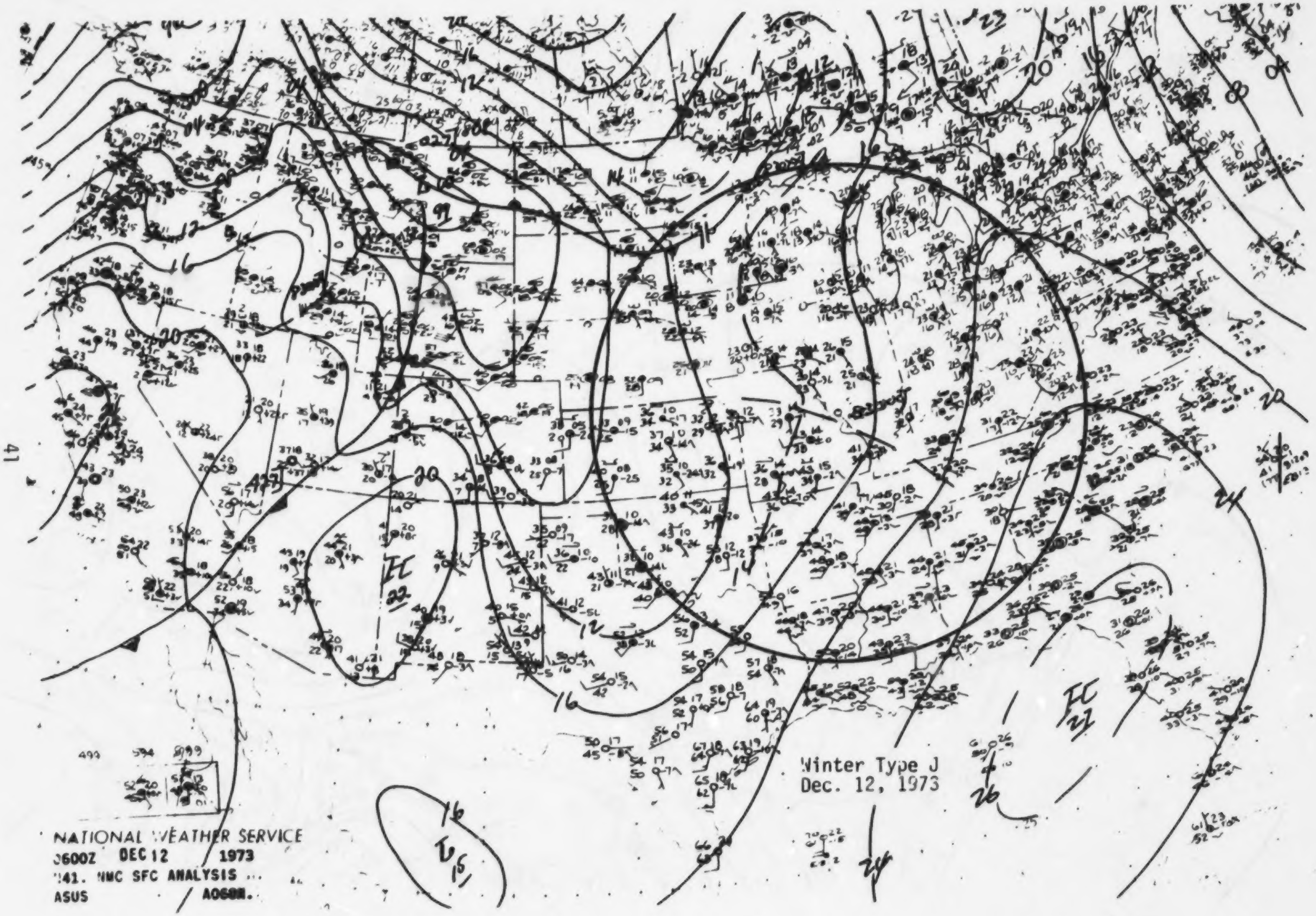


Winter Type I
Jan. 8, 1974



Winter Type J
Dec. 12, 1973

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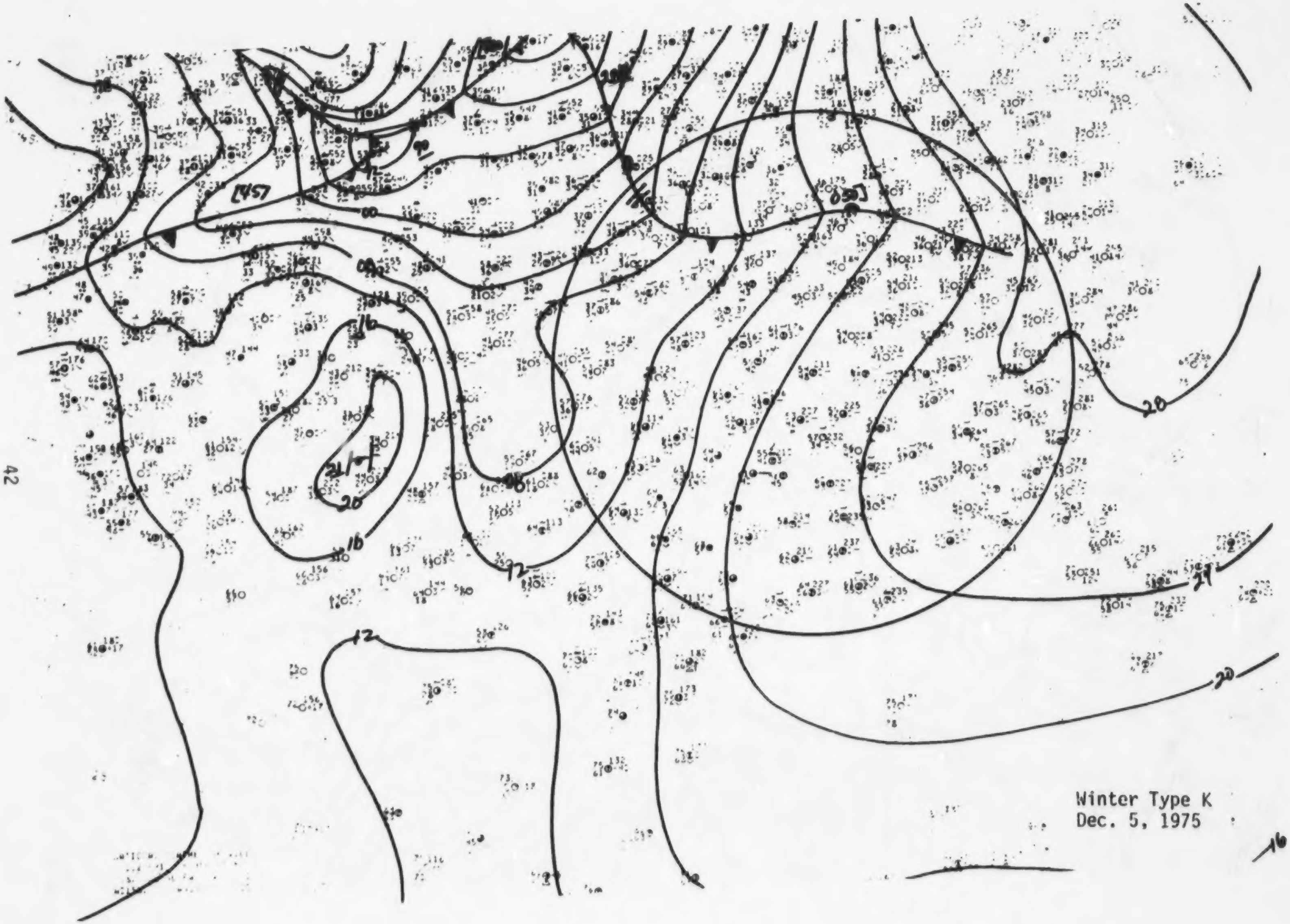

Winter Type K
Dec. 5, 1975

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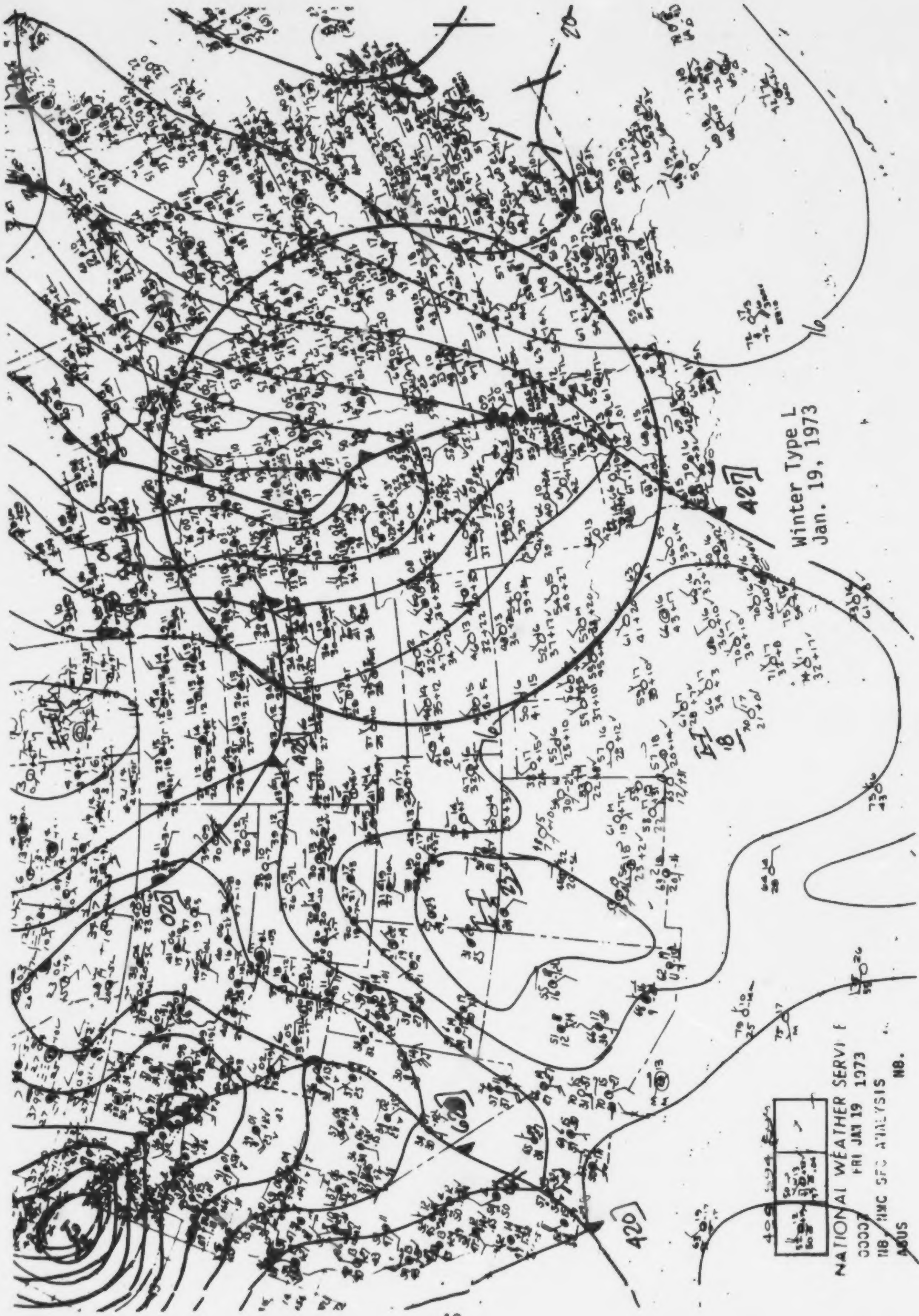

Winter Type L
Jan. 19, 1973

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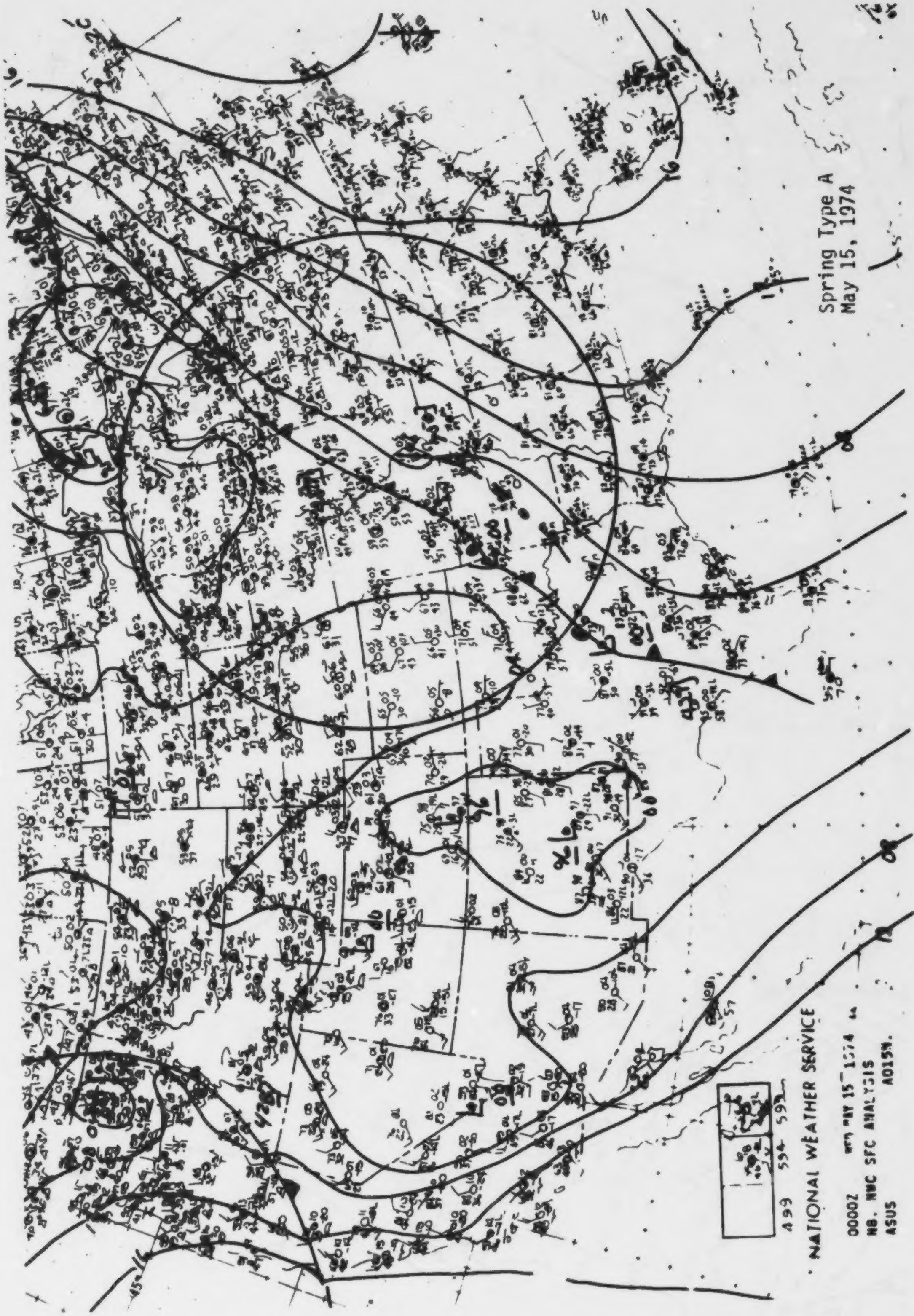
Appendix A - Section 2

Spring Map Types



Spring Type A
May 15, 1974

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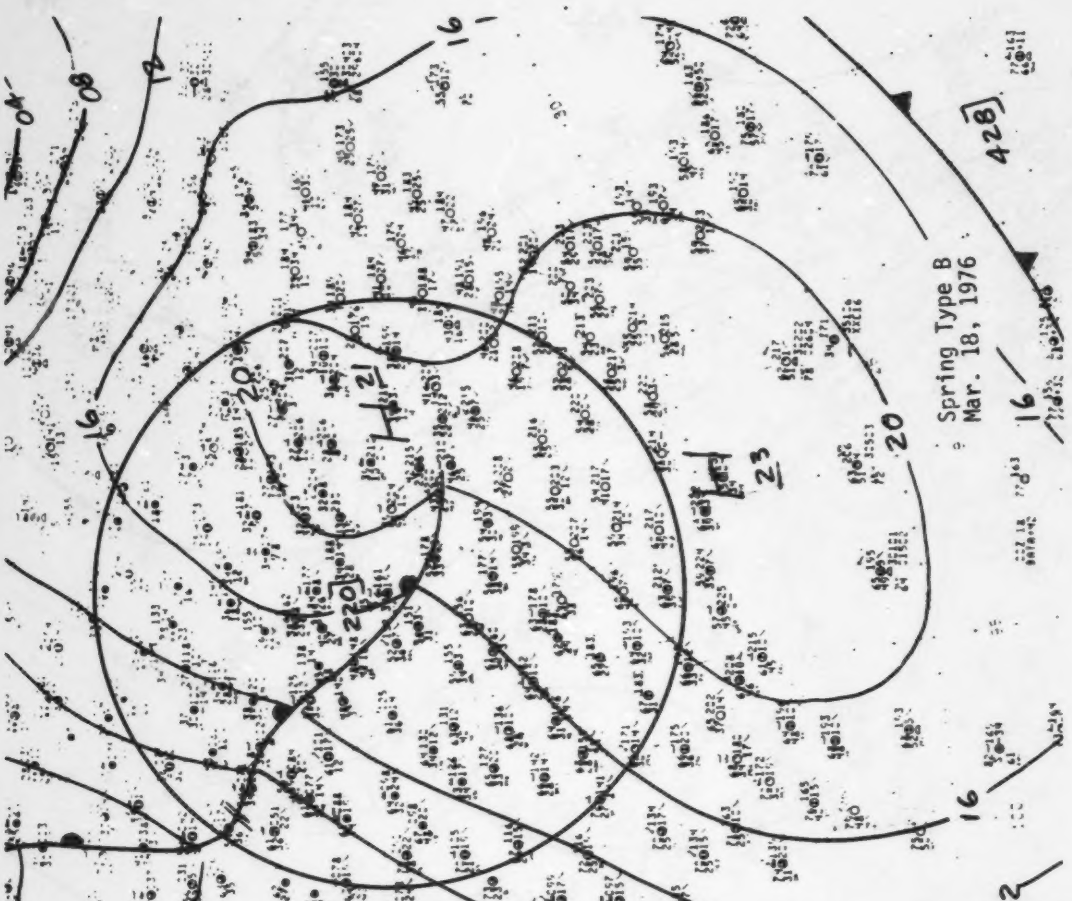

Spring Type B
Mar. 18, 1976

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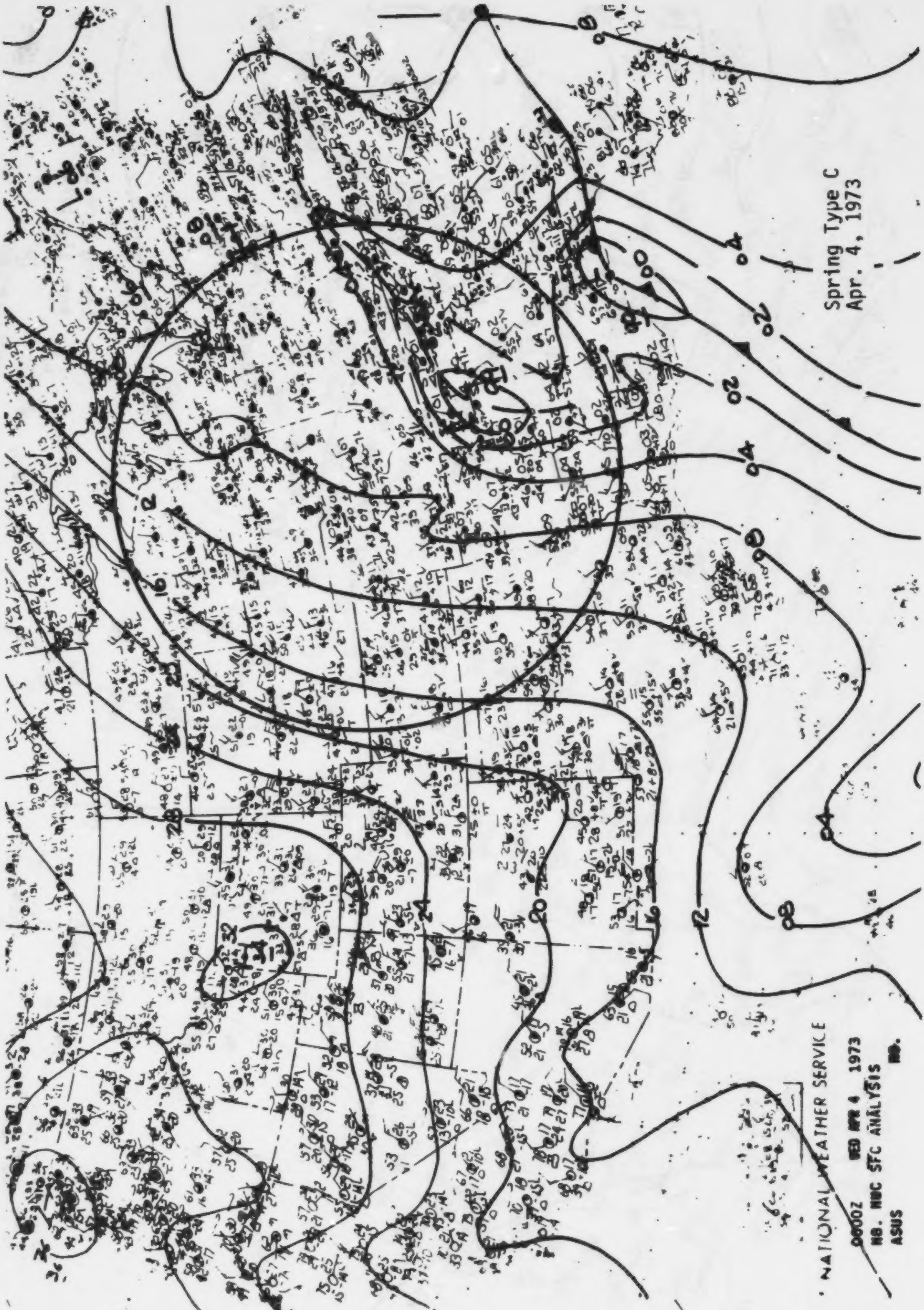

Spring Type C
Apr. 4, 1973

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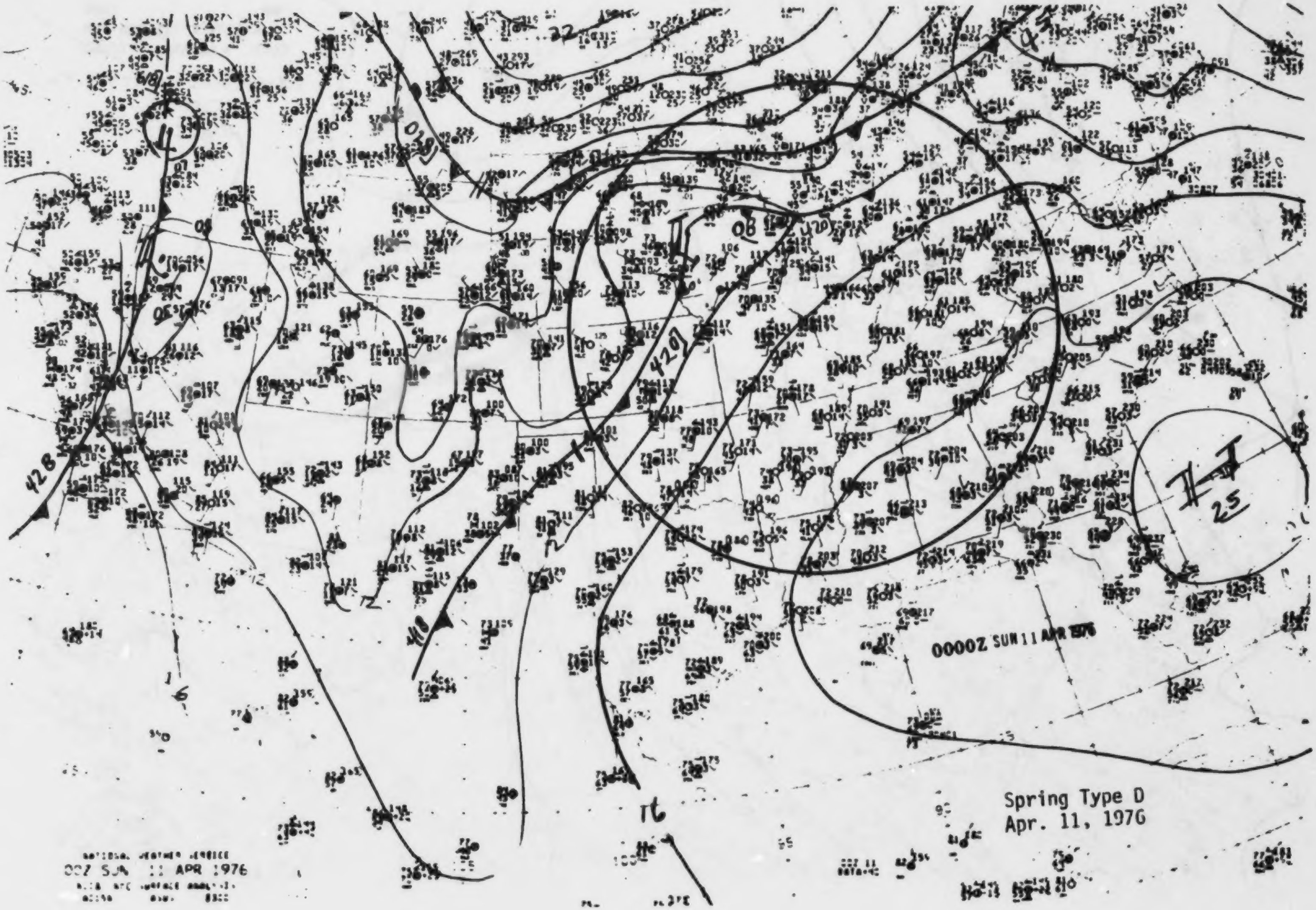
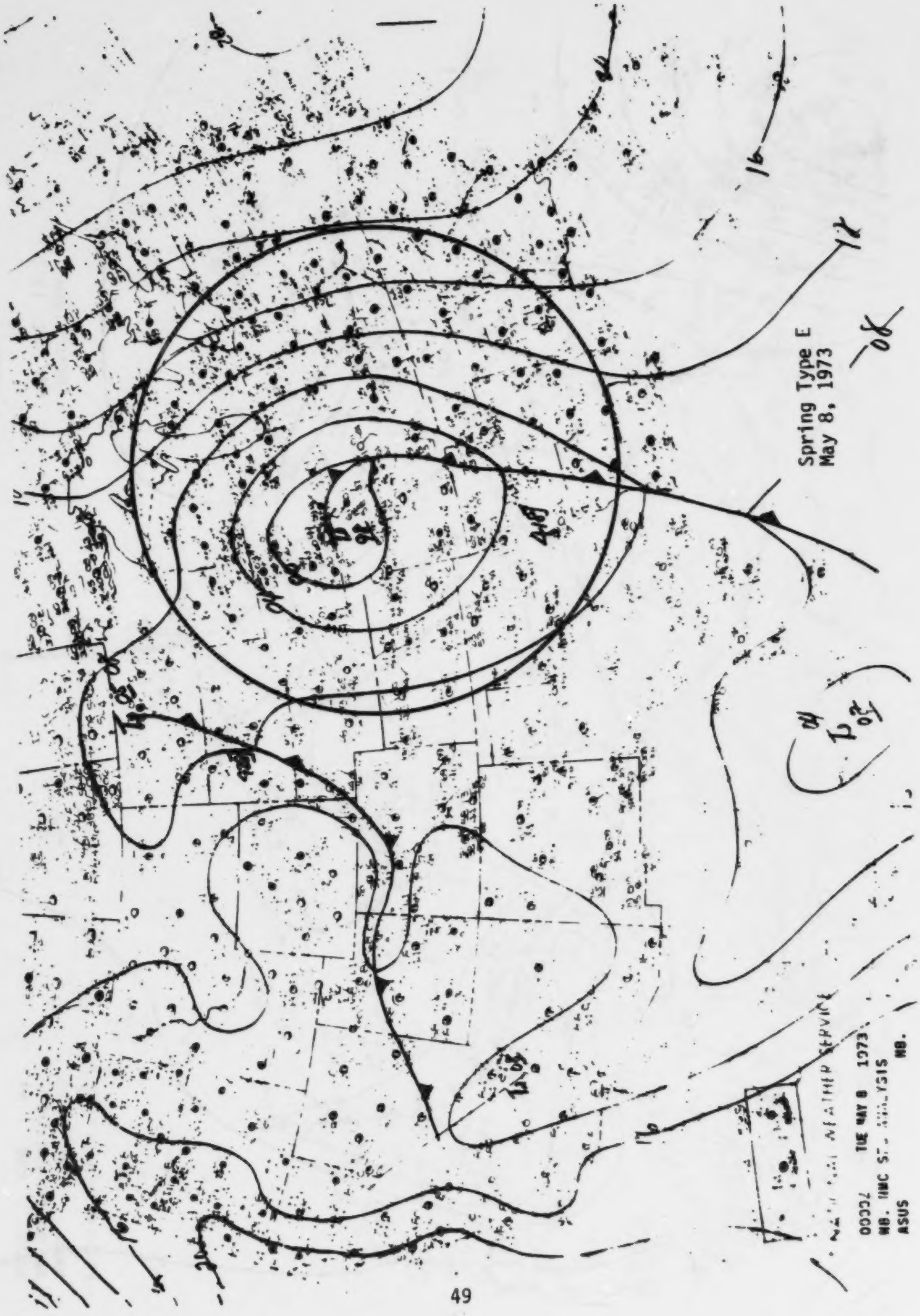
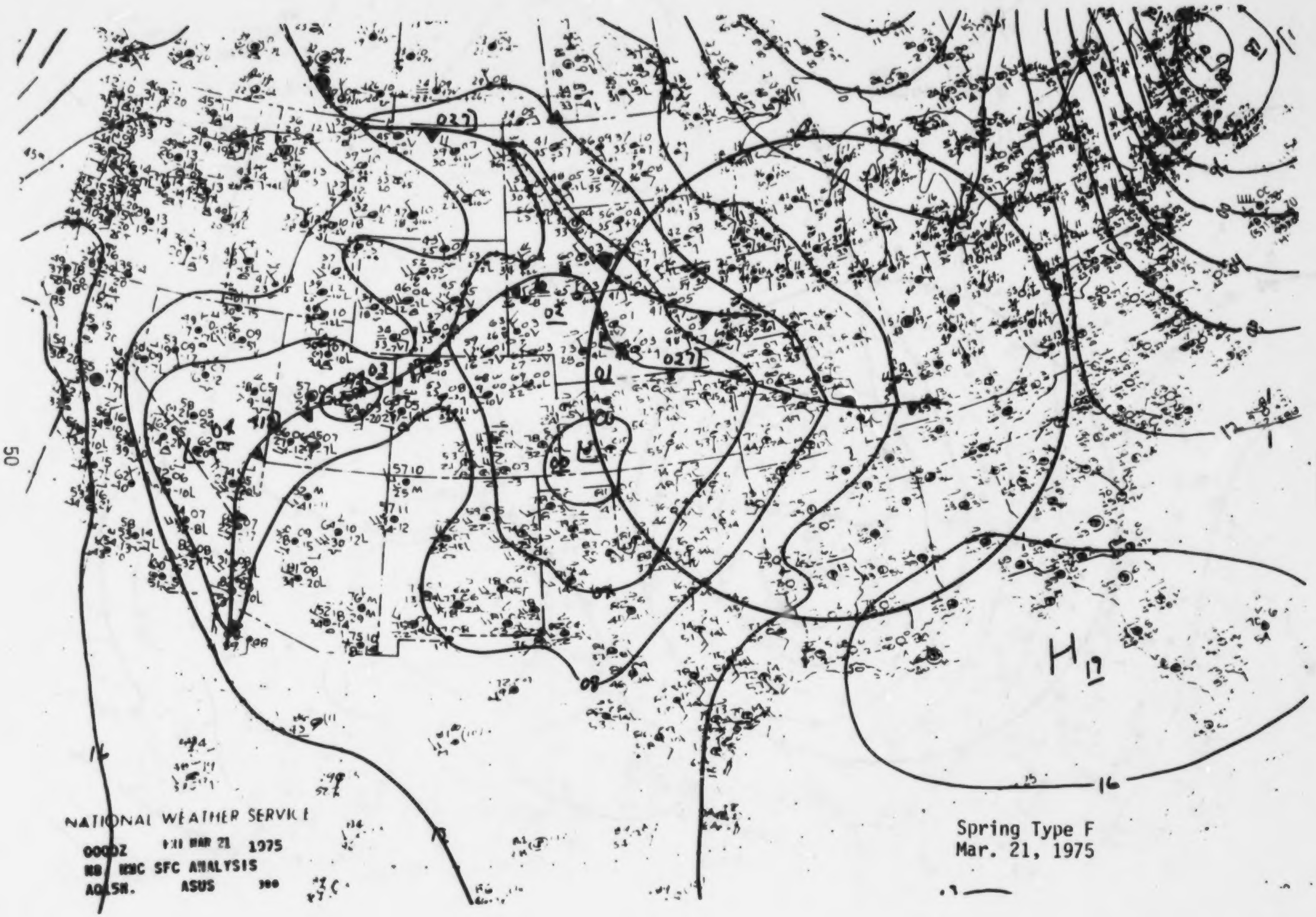


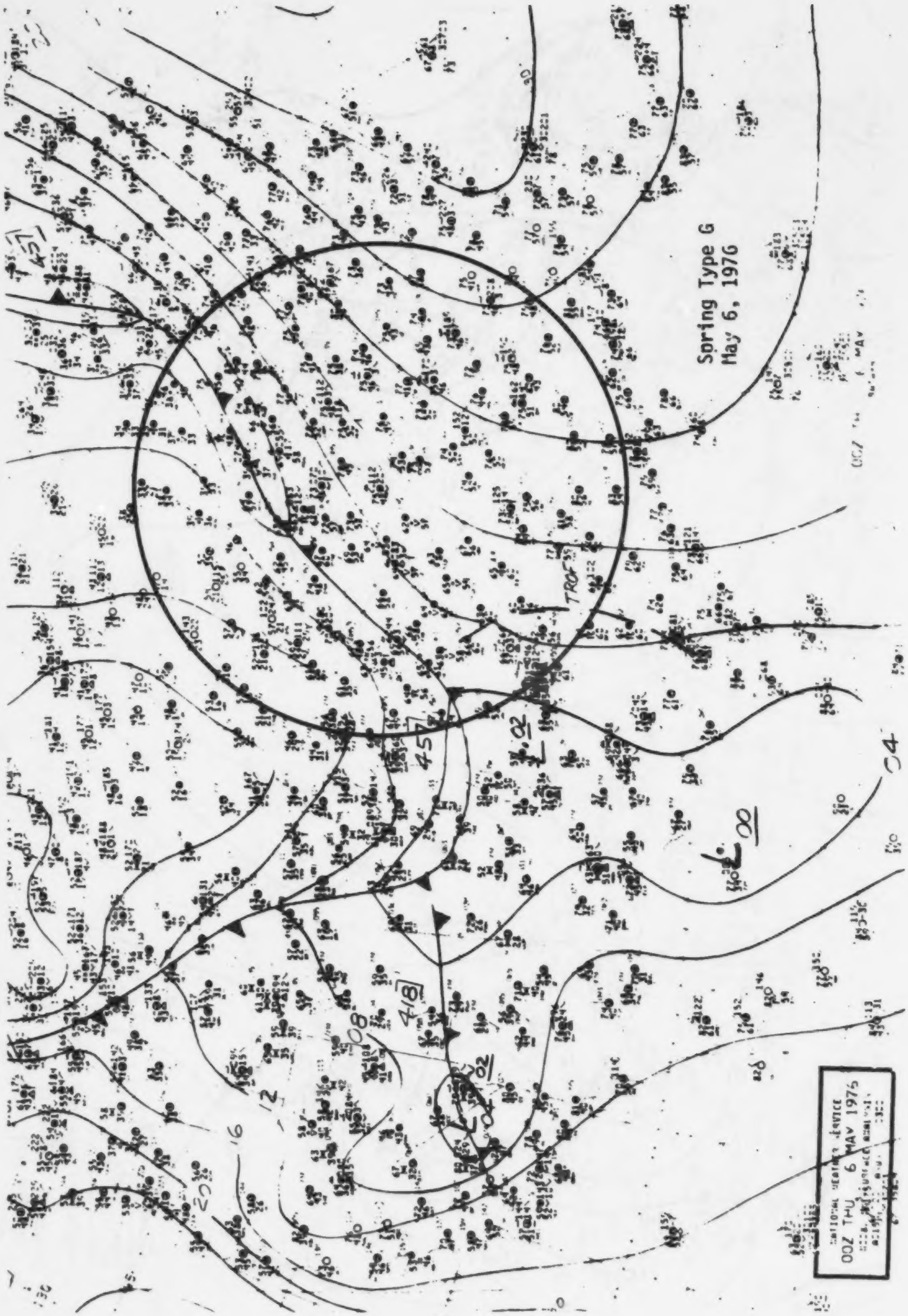
Spring Type D
Apr. 11, 1976



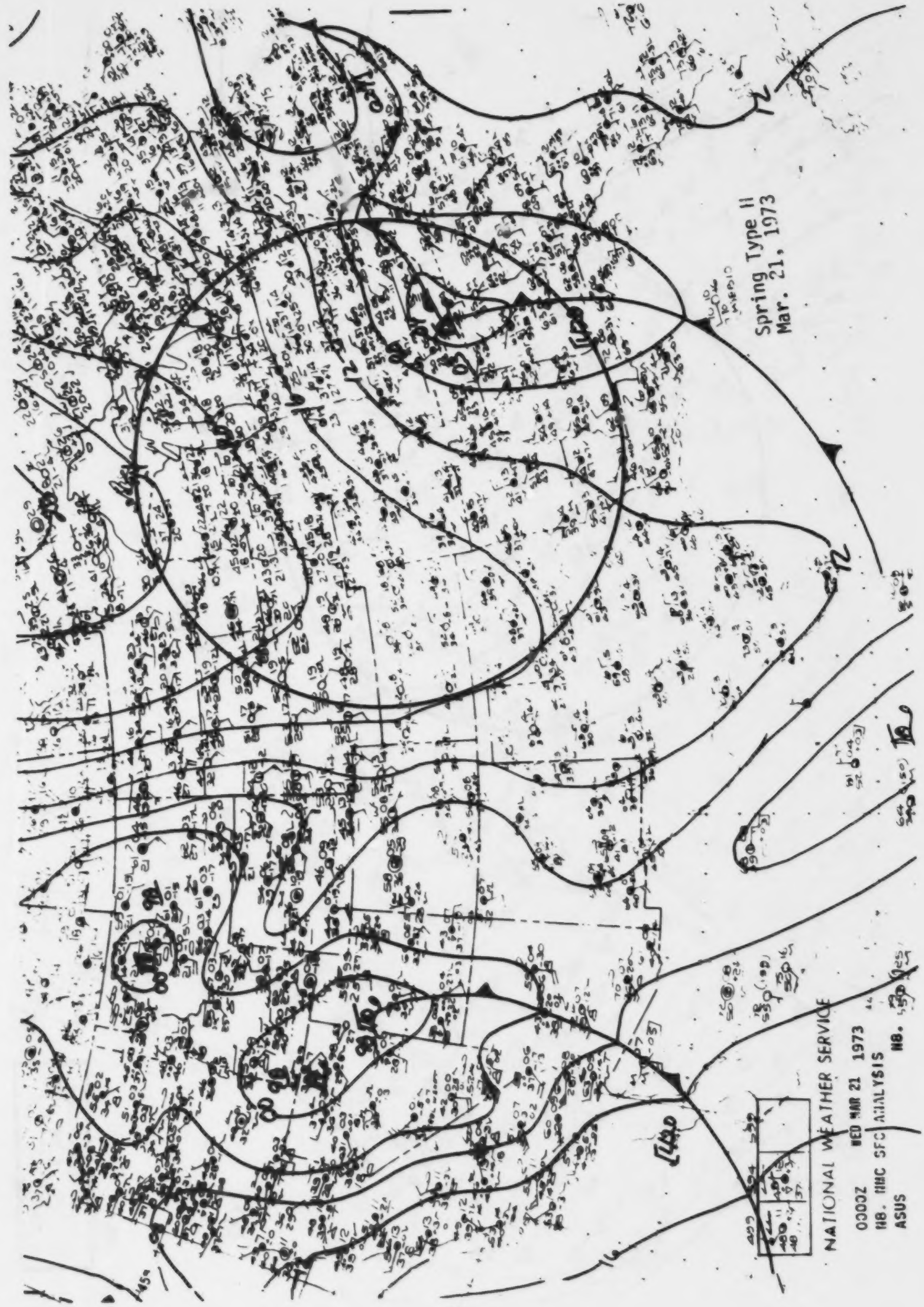
Spring Type E
May 8, 1973



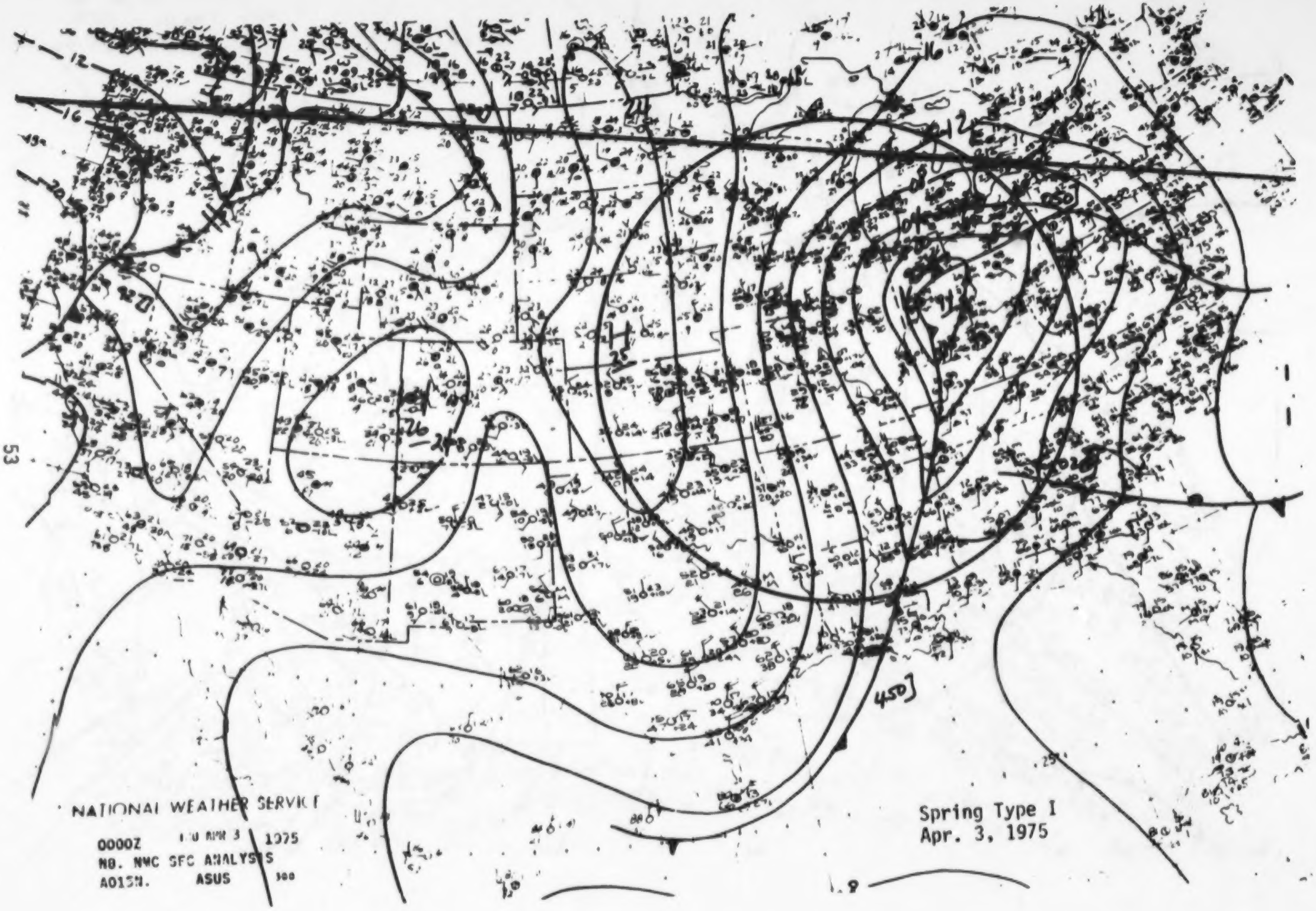
Spring Type F
Mar. 21, 1975



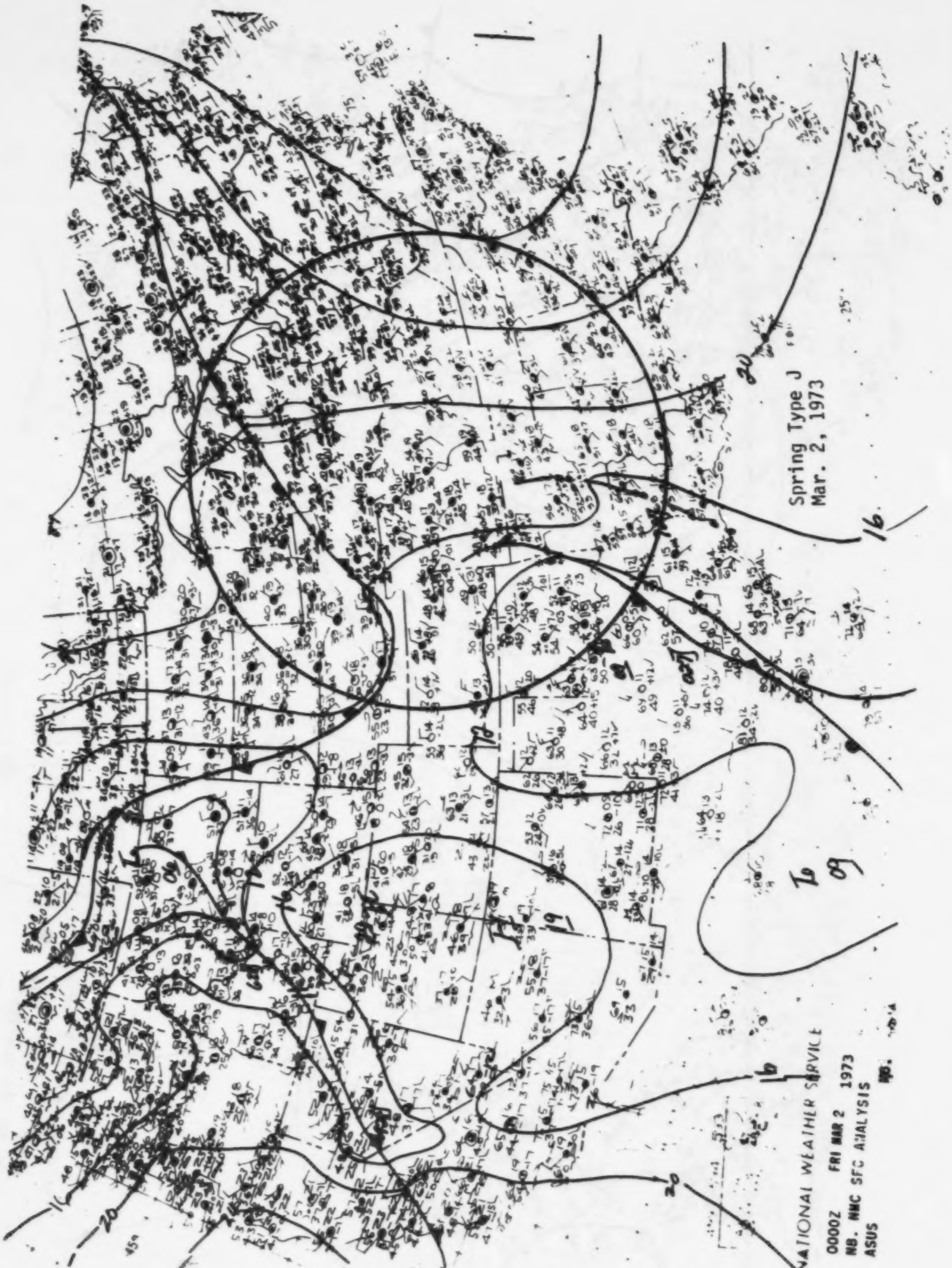
Spring Type G
May 6, 1976



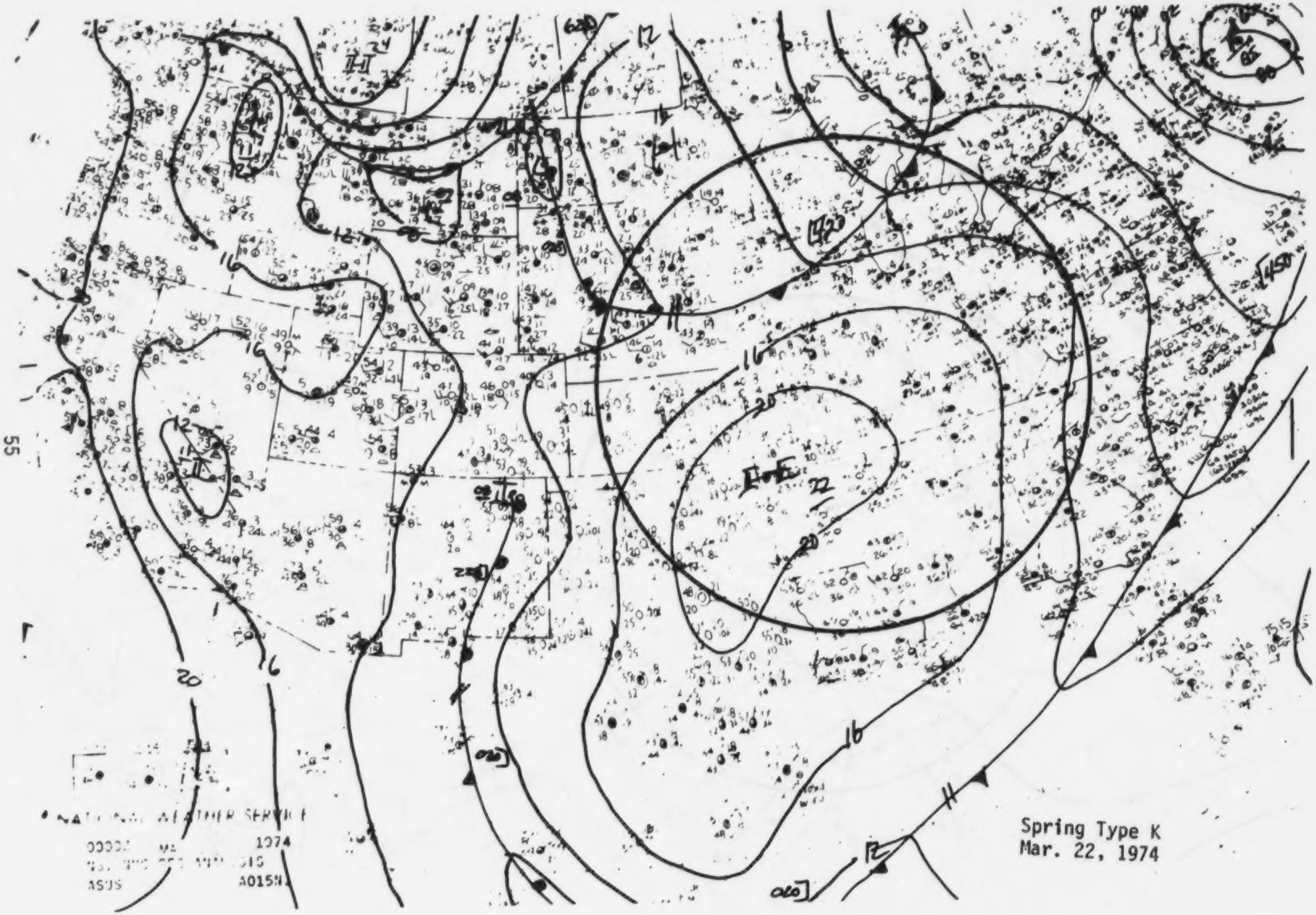
Spring Type II
Mar. 21, 1973



Spring Type I
Apr. 3, 1975



Spring Type J
Mar. 2, 1973



Spring Type K
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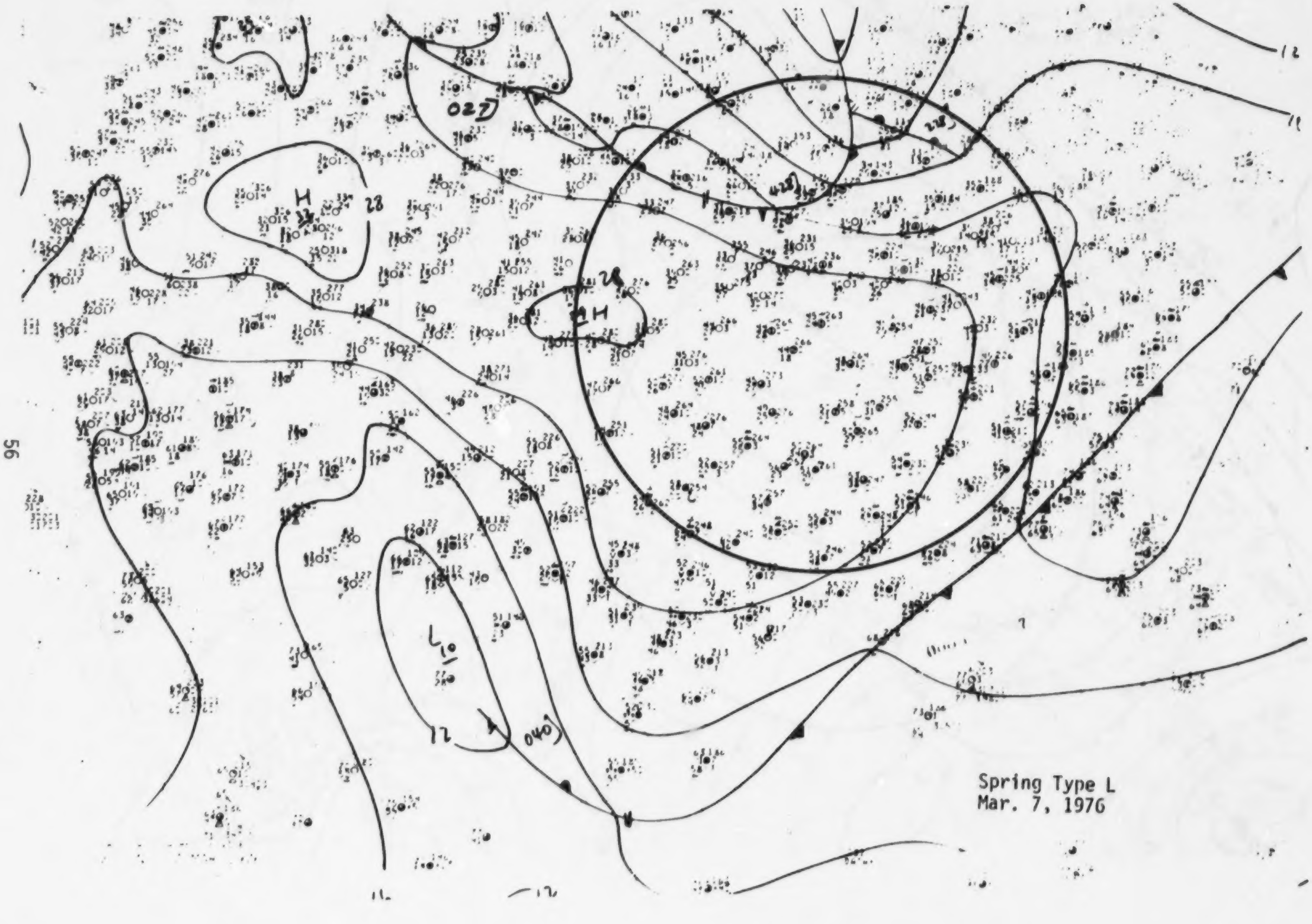
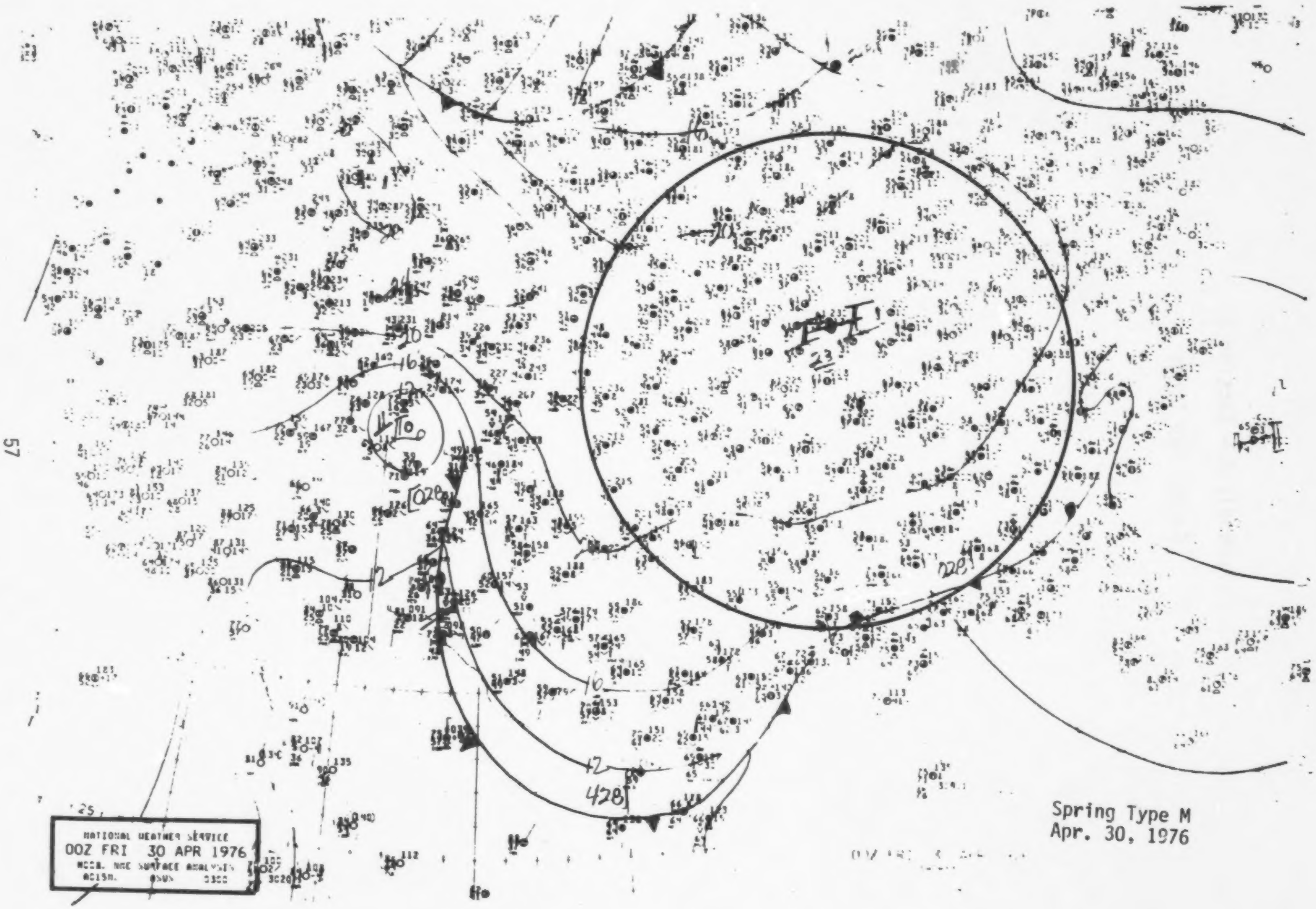


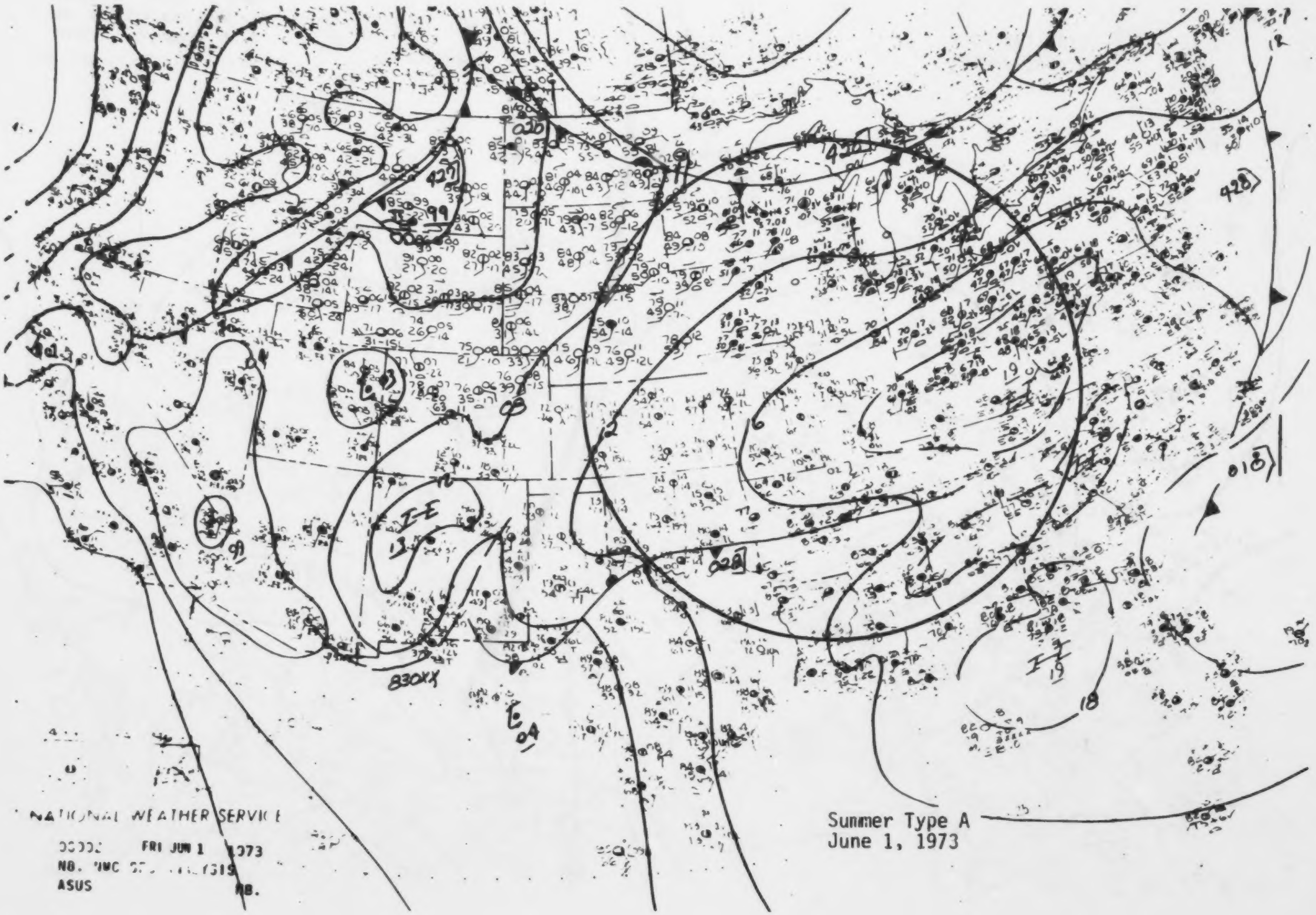
Spring Type L
Mar. 7, 1976



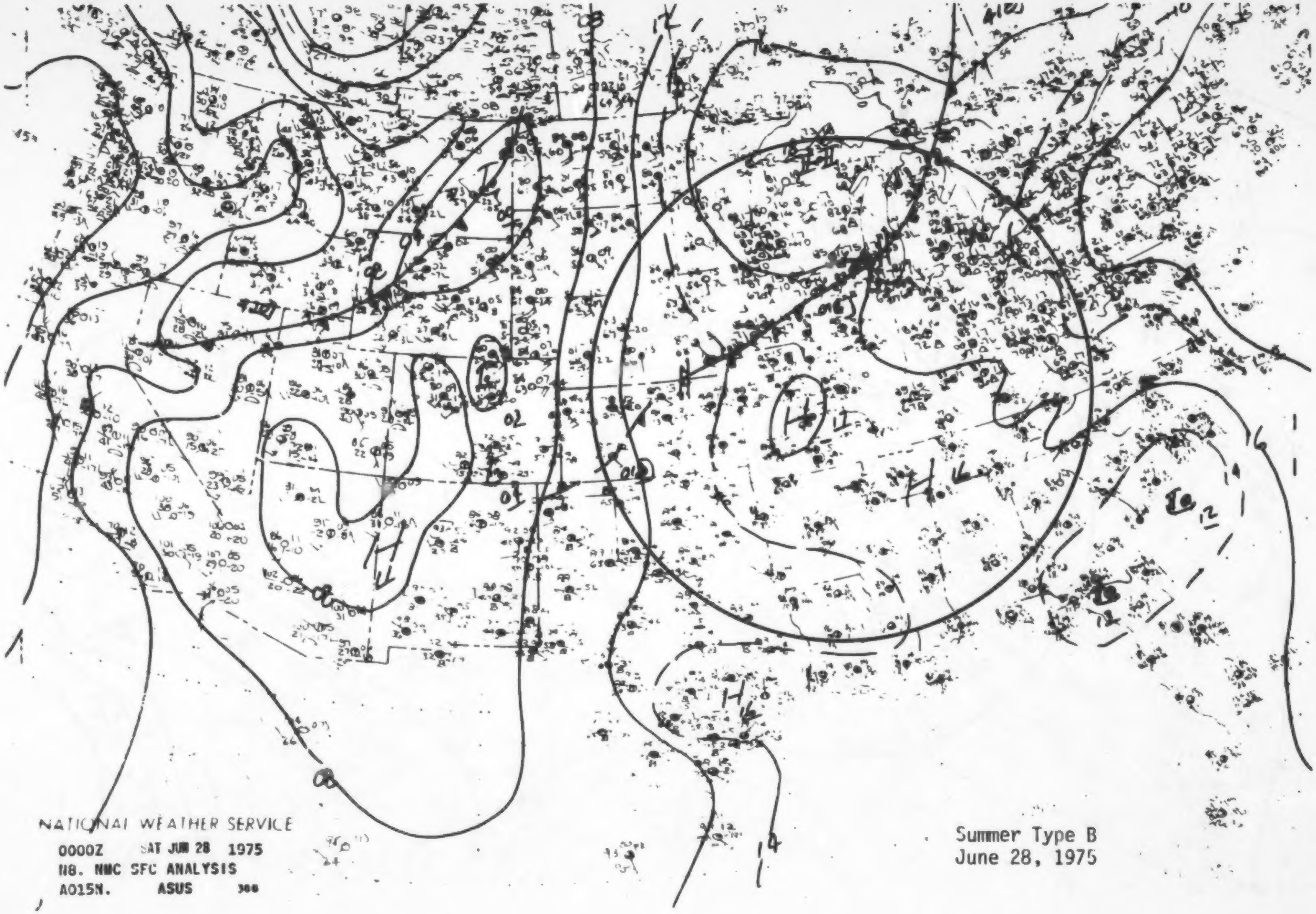
Spring Type M
Apr. 30, 1976

Appendix A - Section 3

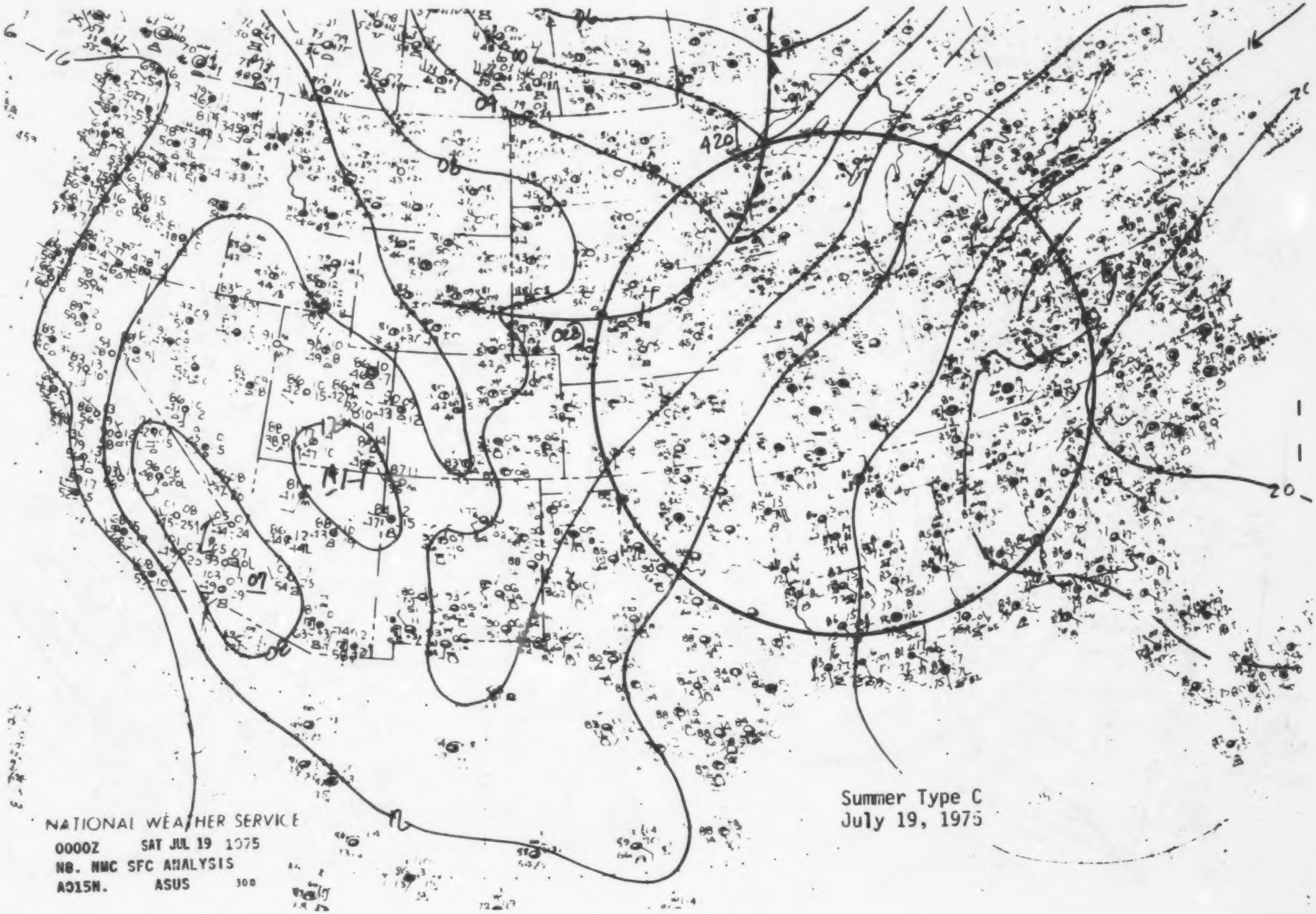
Summer Map Types



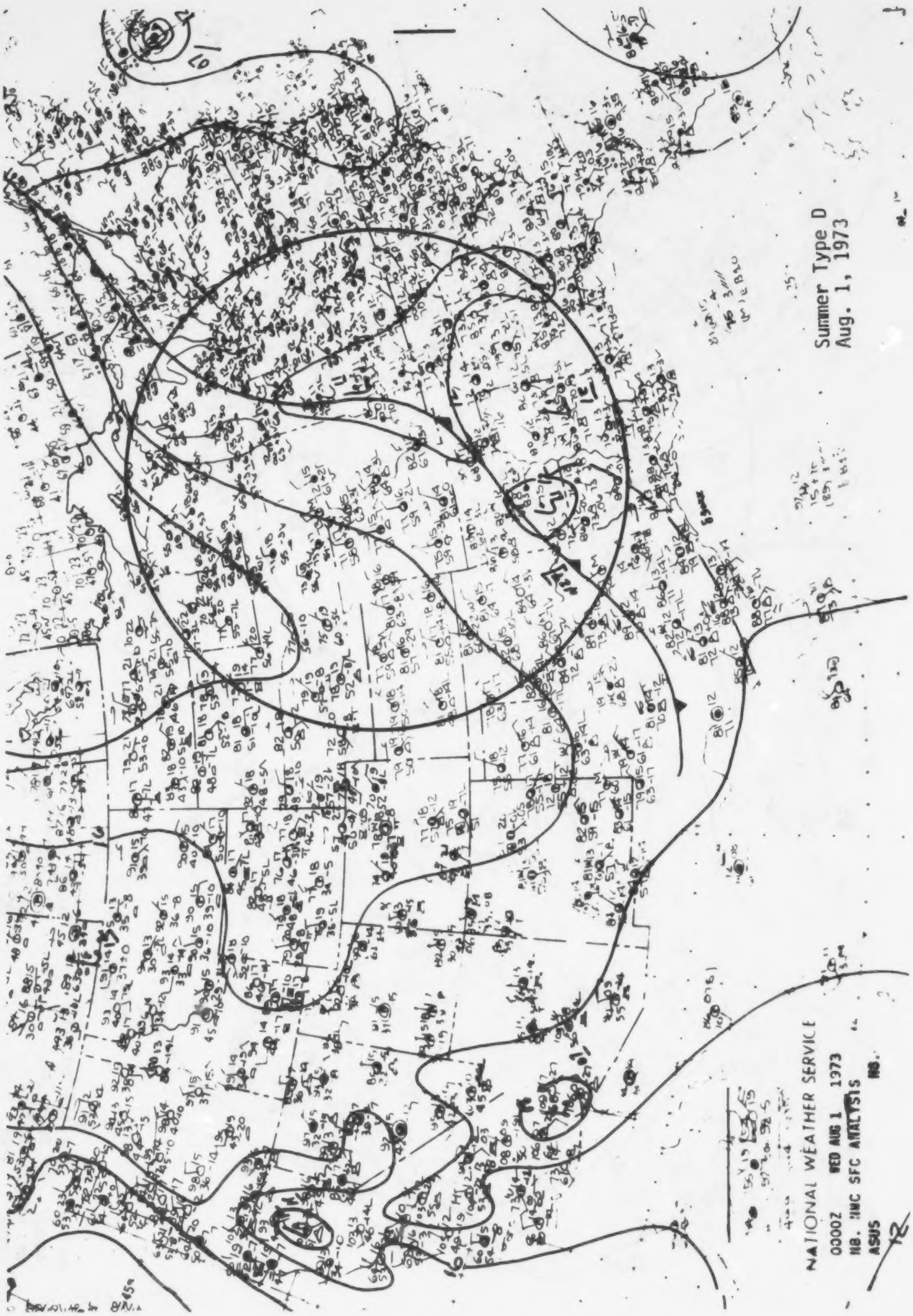
Summer Type A
June 1, 1973



Summer Type B
June 28, 1975



Summer Type C
July 19, 1975



Summer Type D
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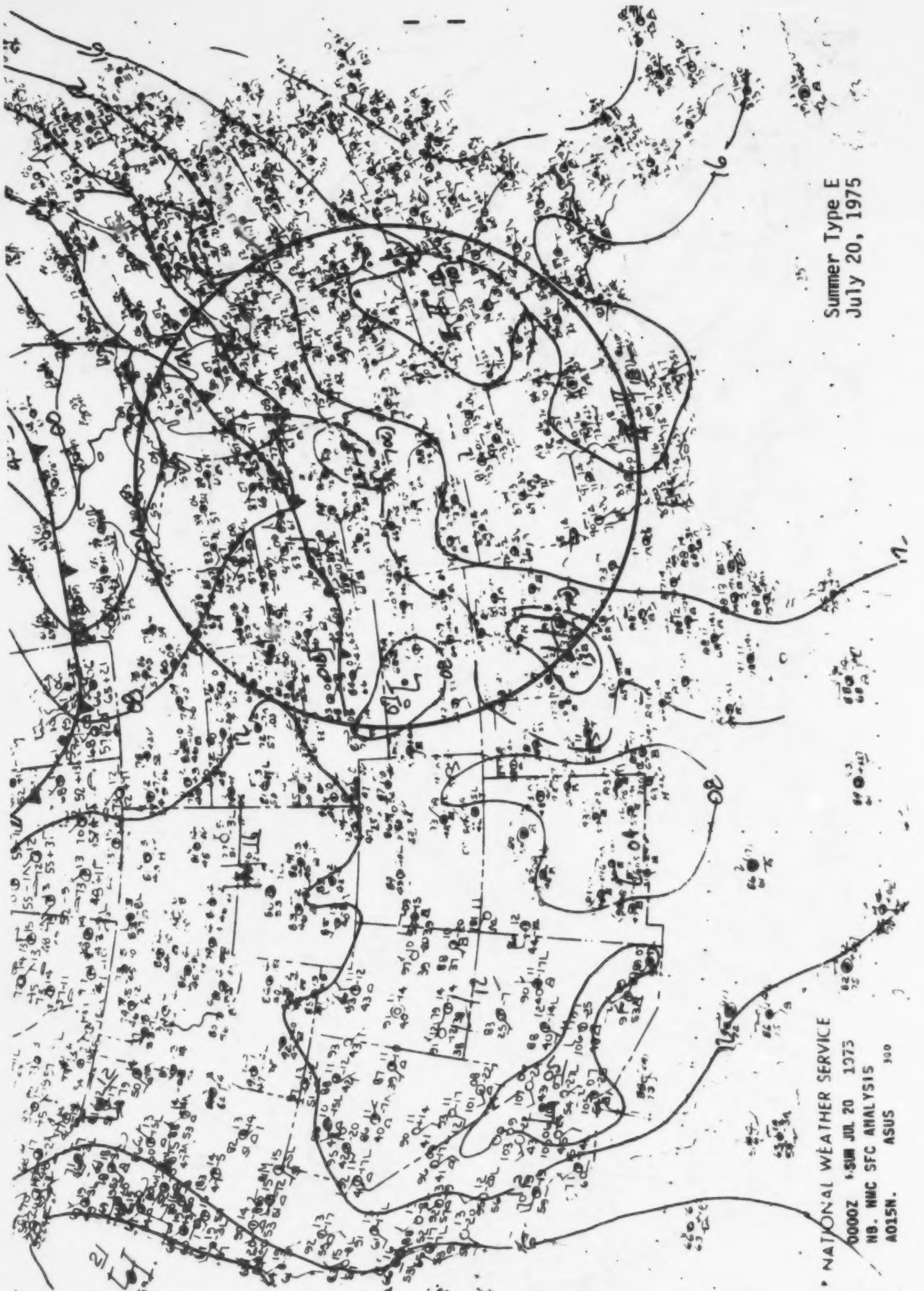

Summer Type E
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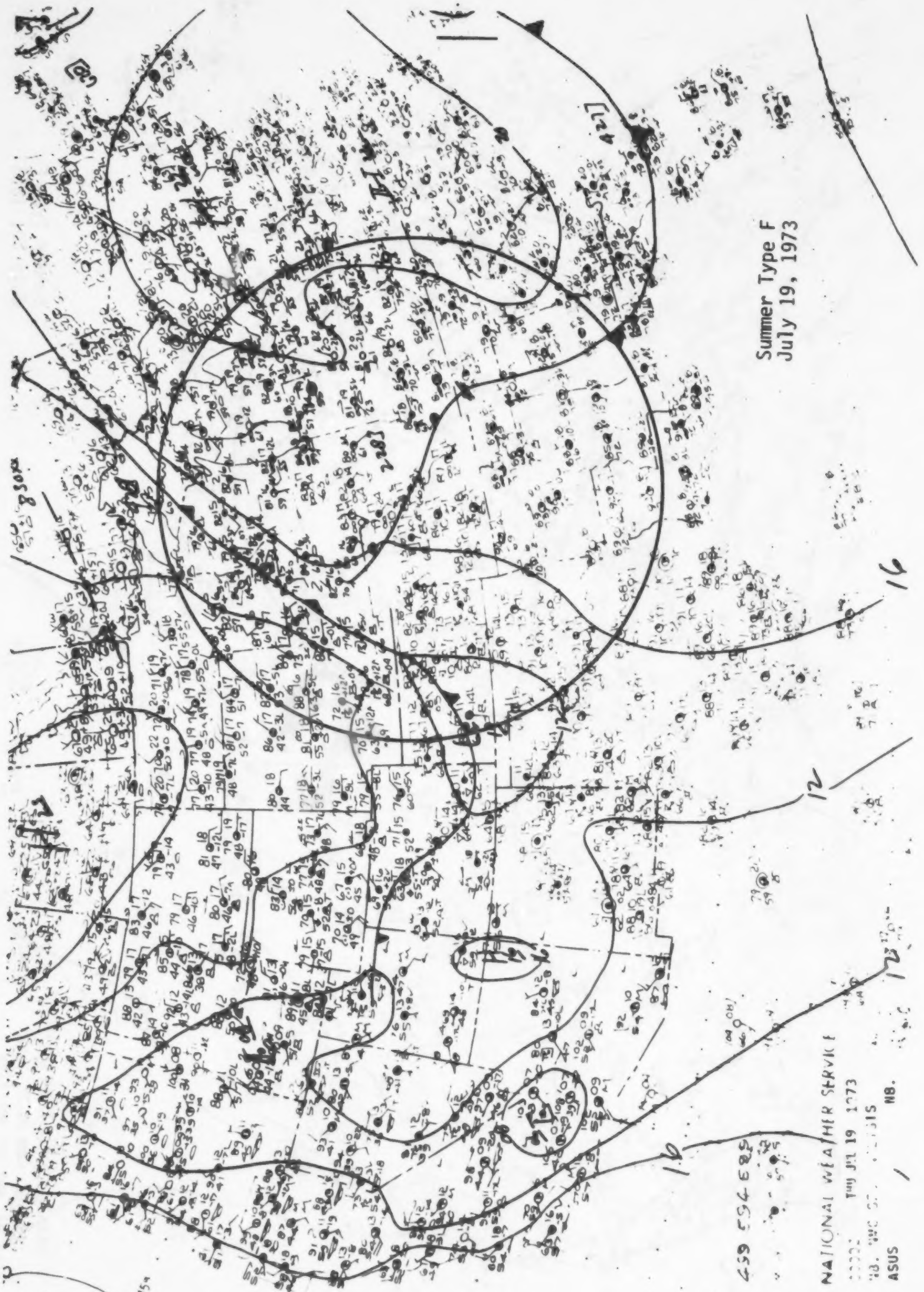
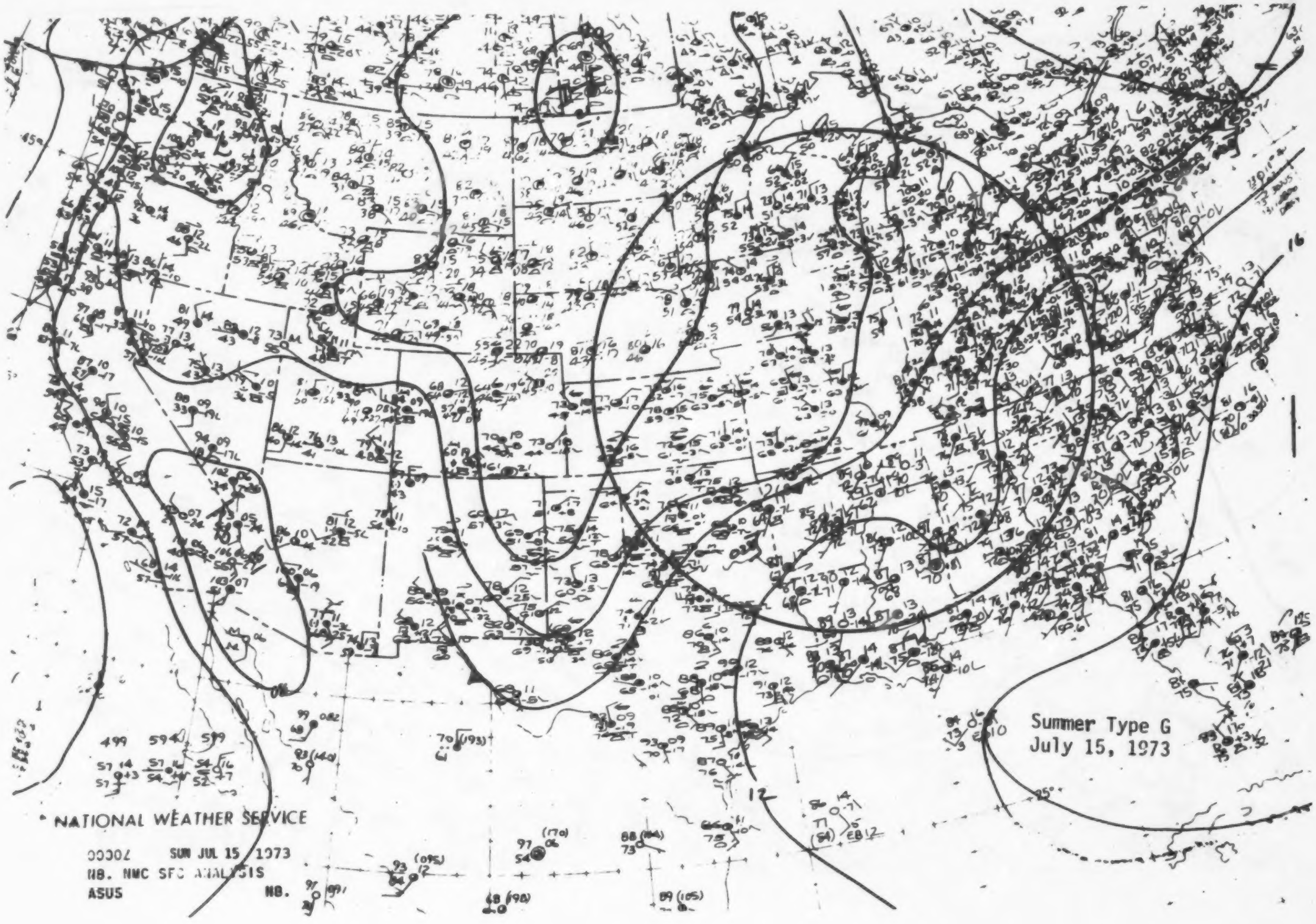
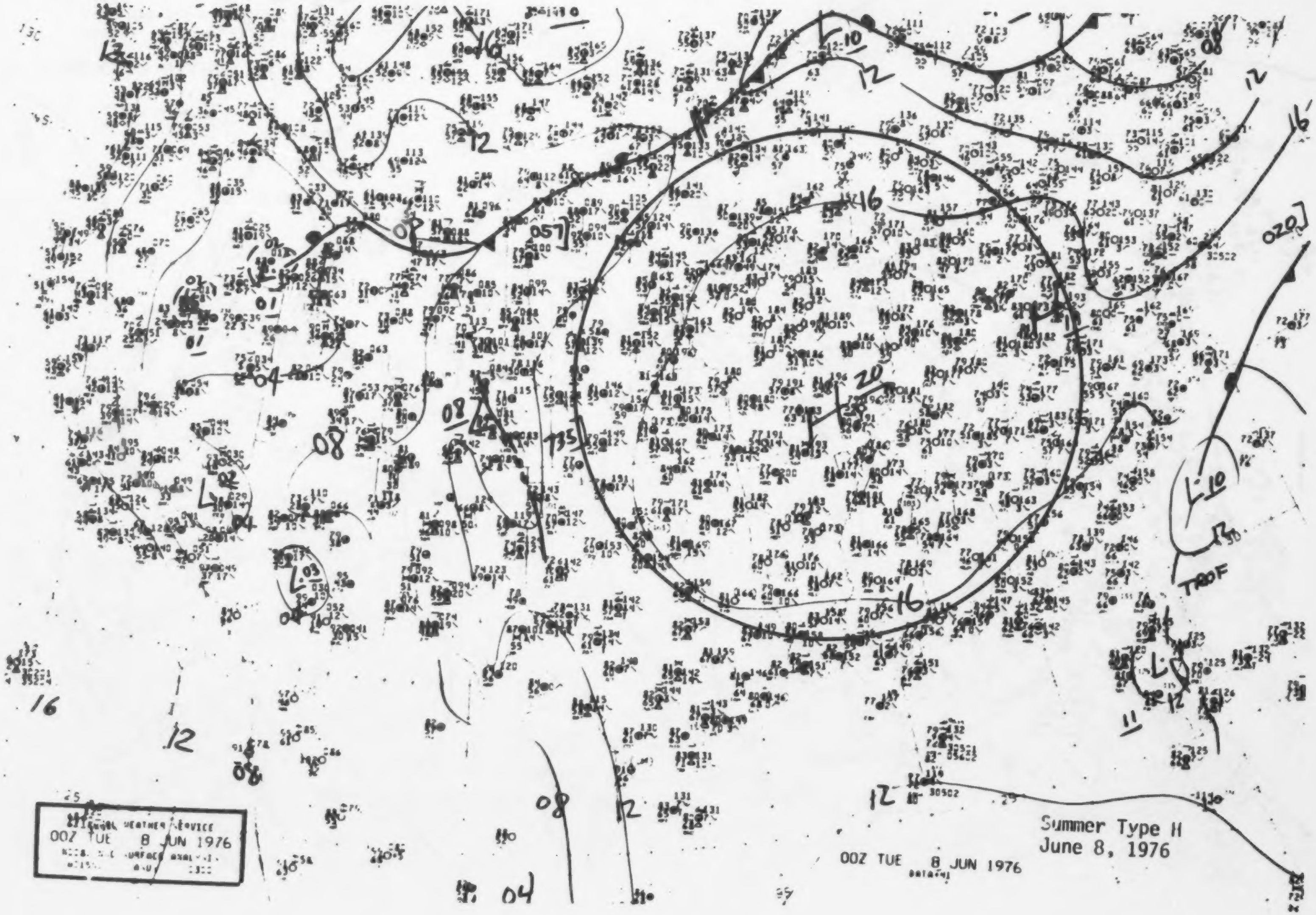


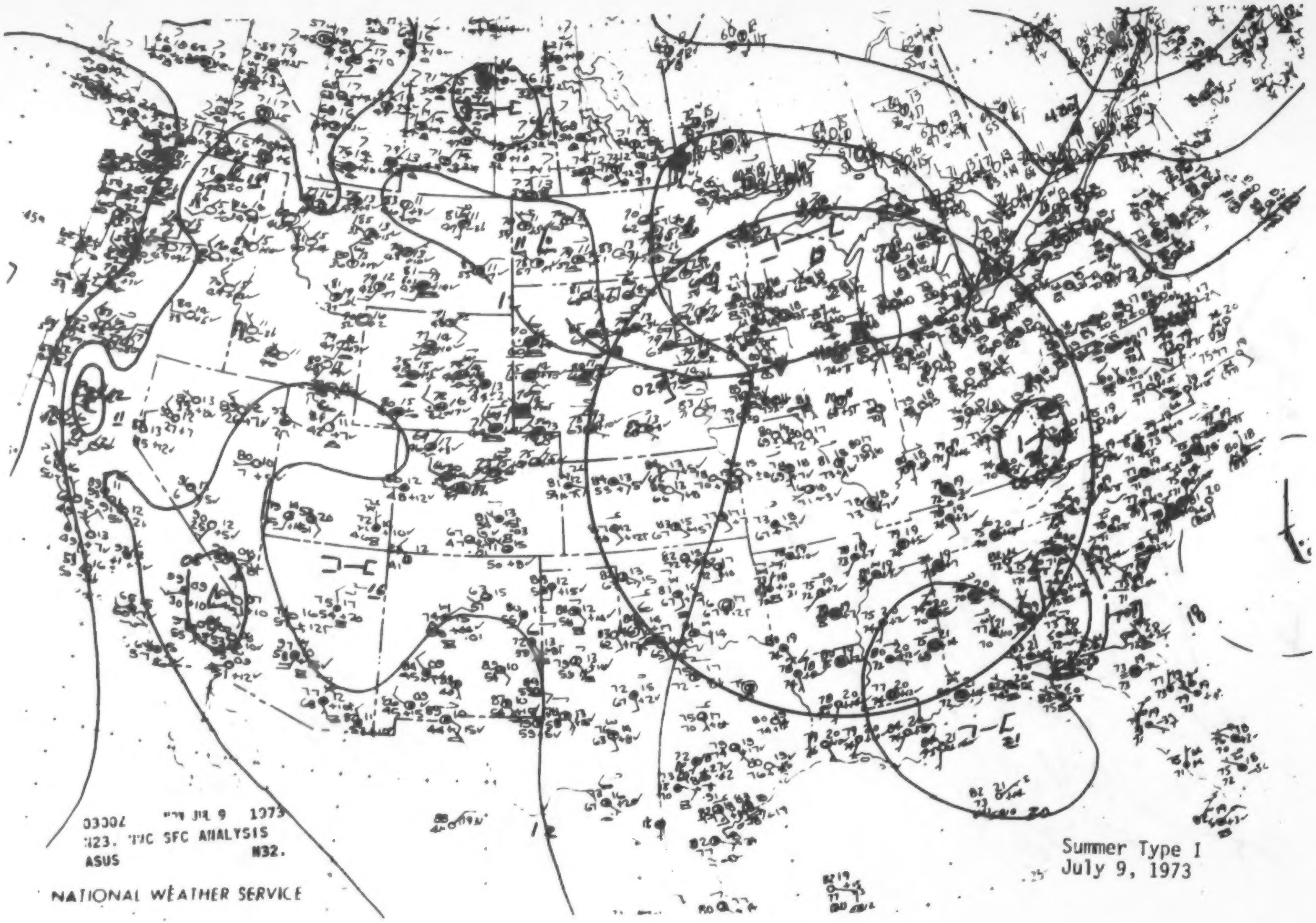
Summer Type F
July 19, 1973



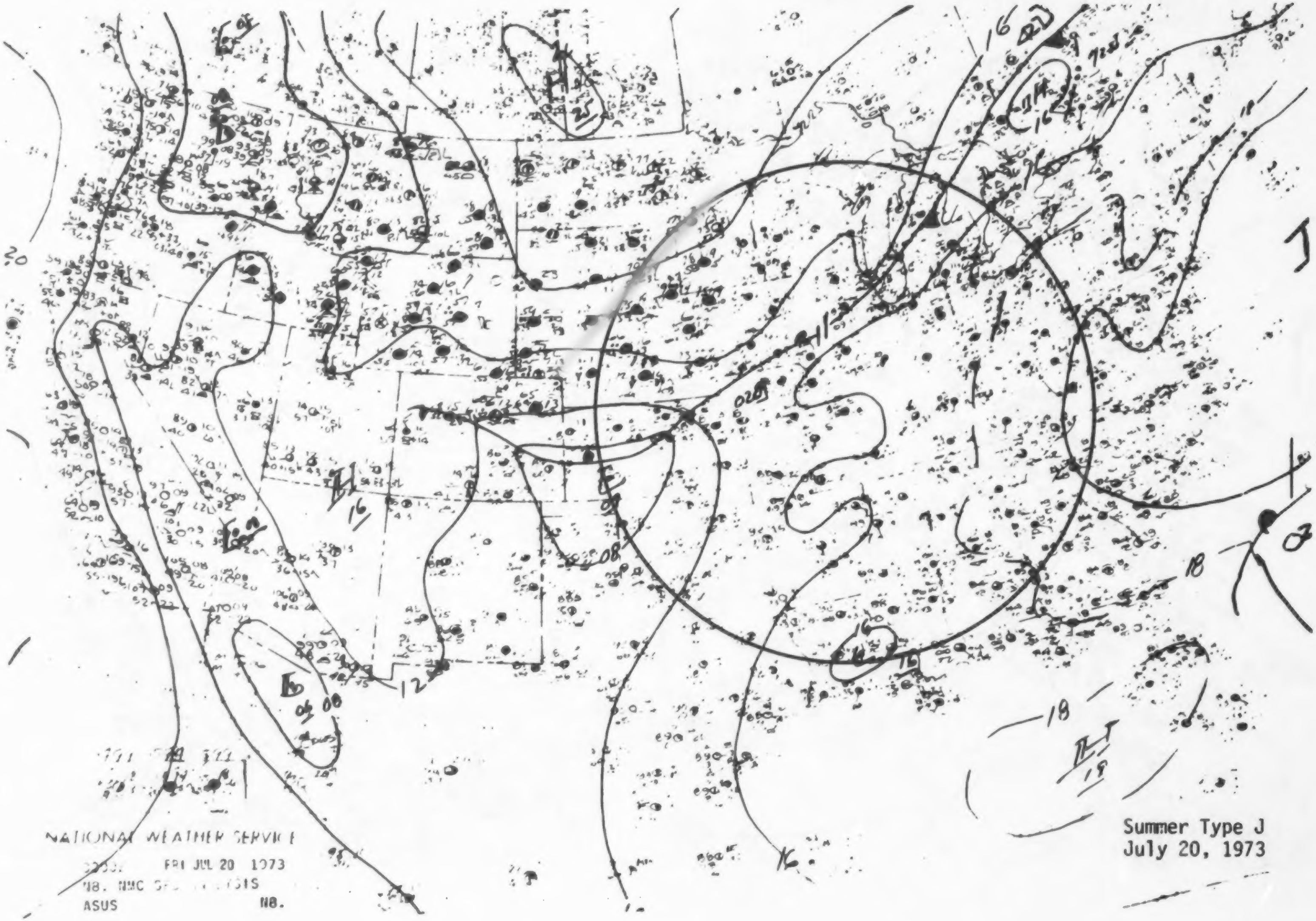
Summer Type G
July 15, 1973



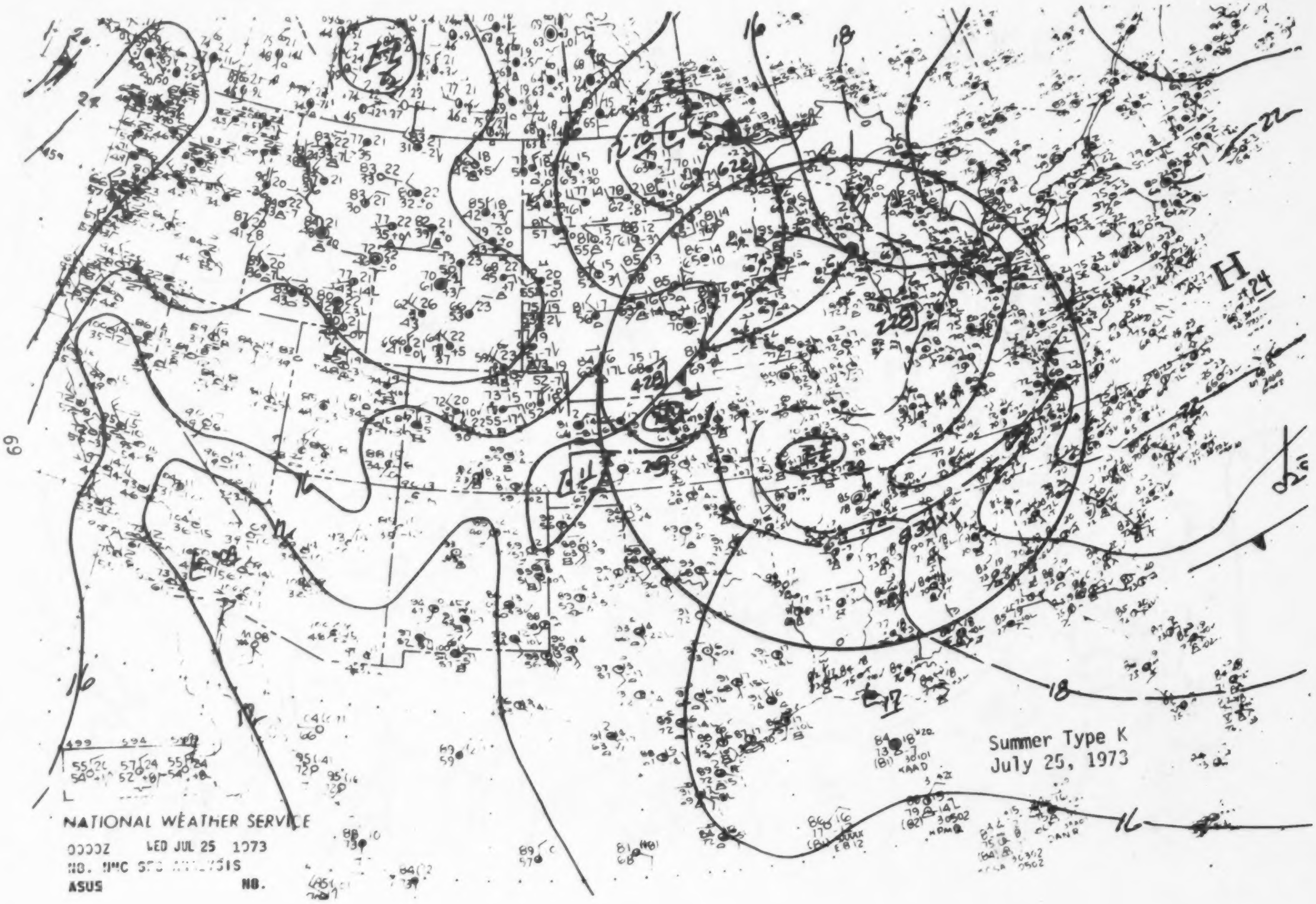
Summer Type II
June 8, 1976



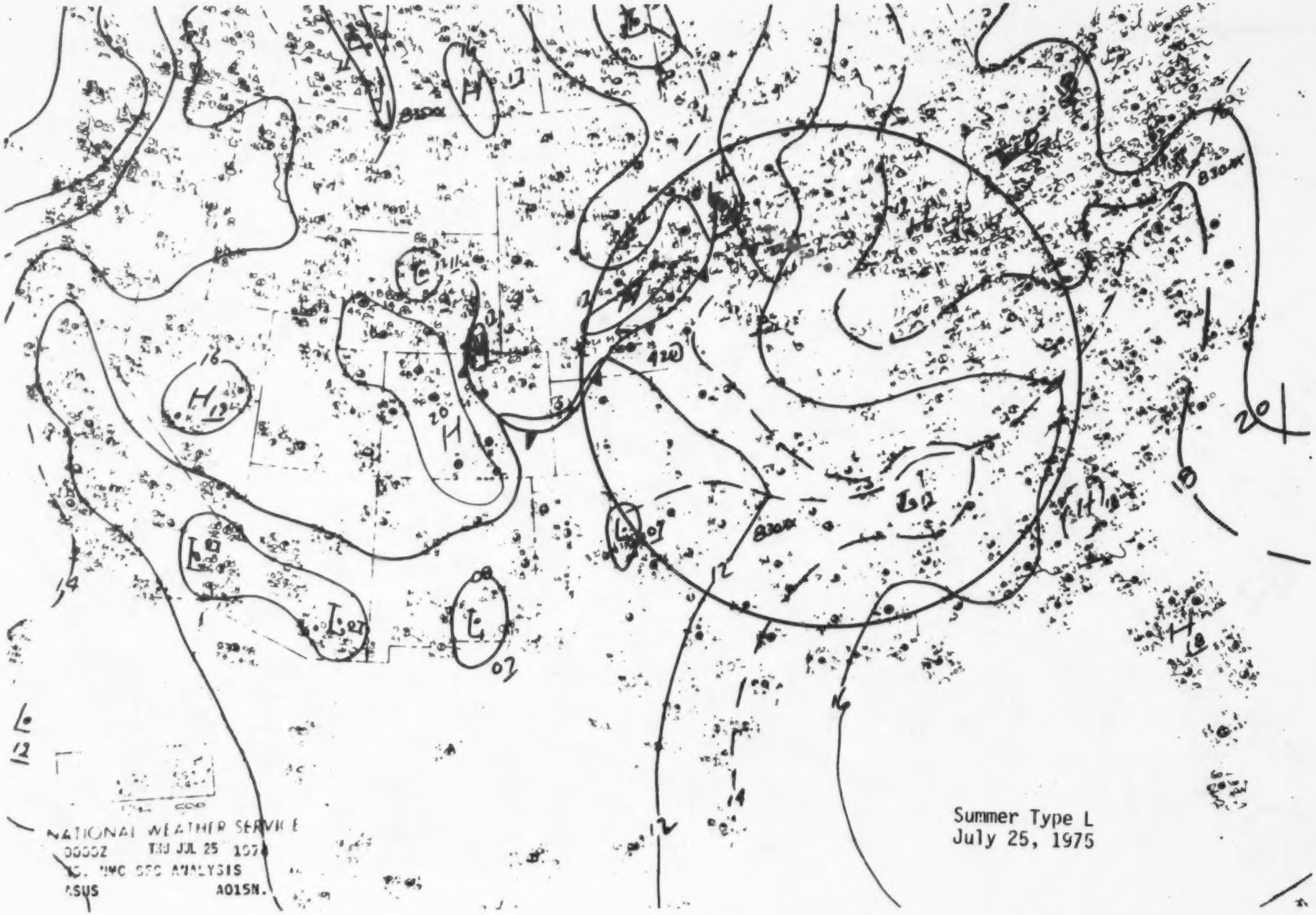
Summer Type I
July 9, 1973



Summer Type J
July 20, 1973

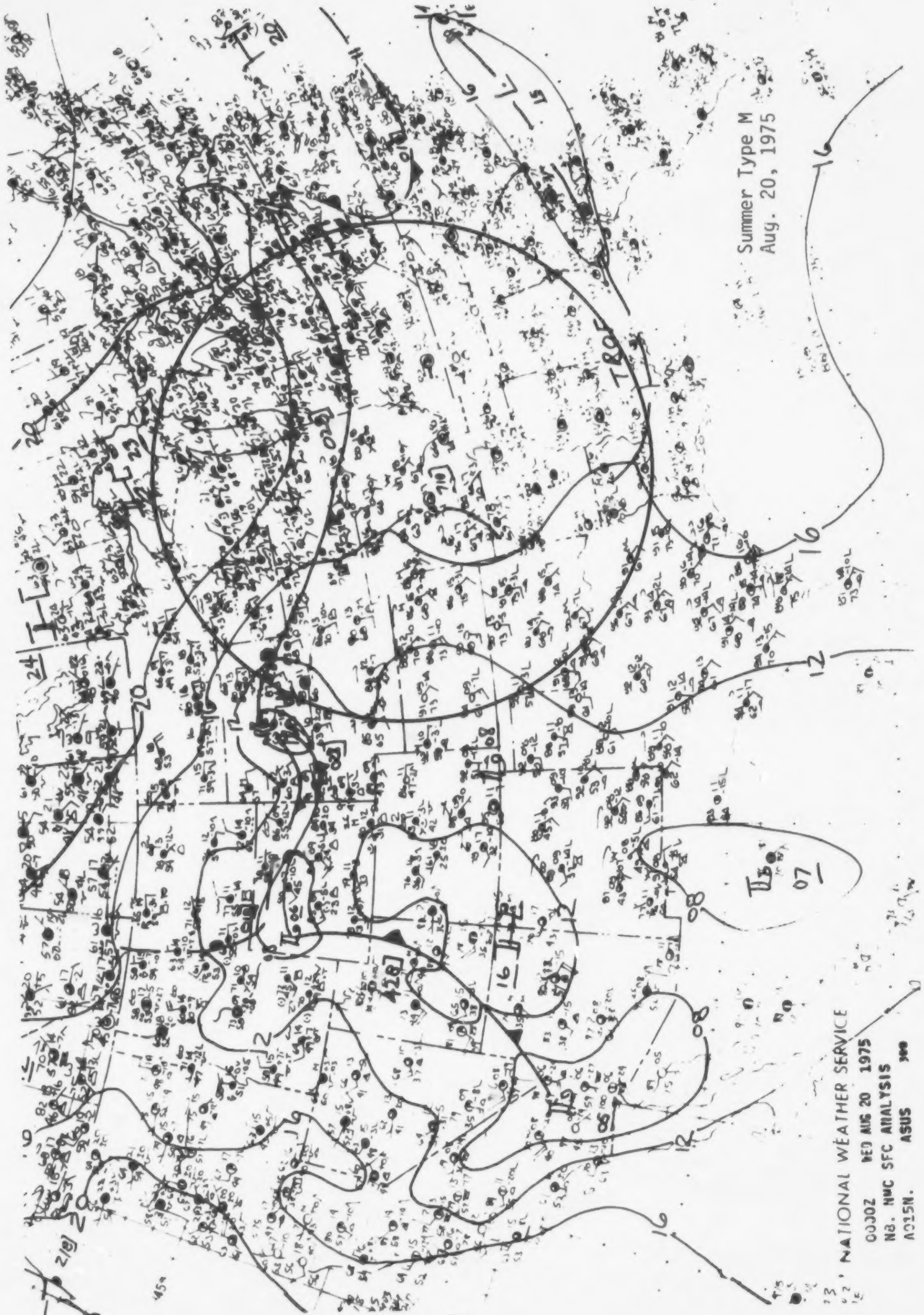


Summer Type K
July 25, 1973



Summer Type L
July 25, 1975

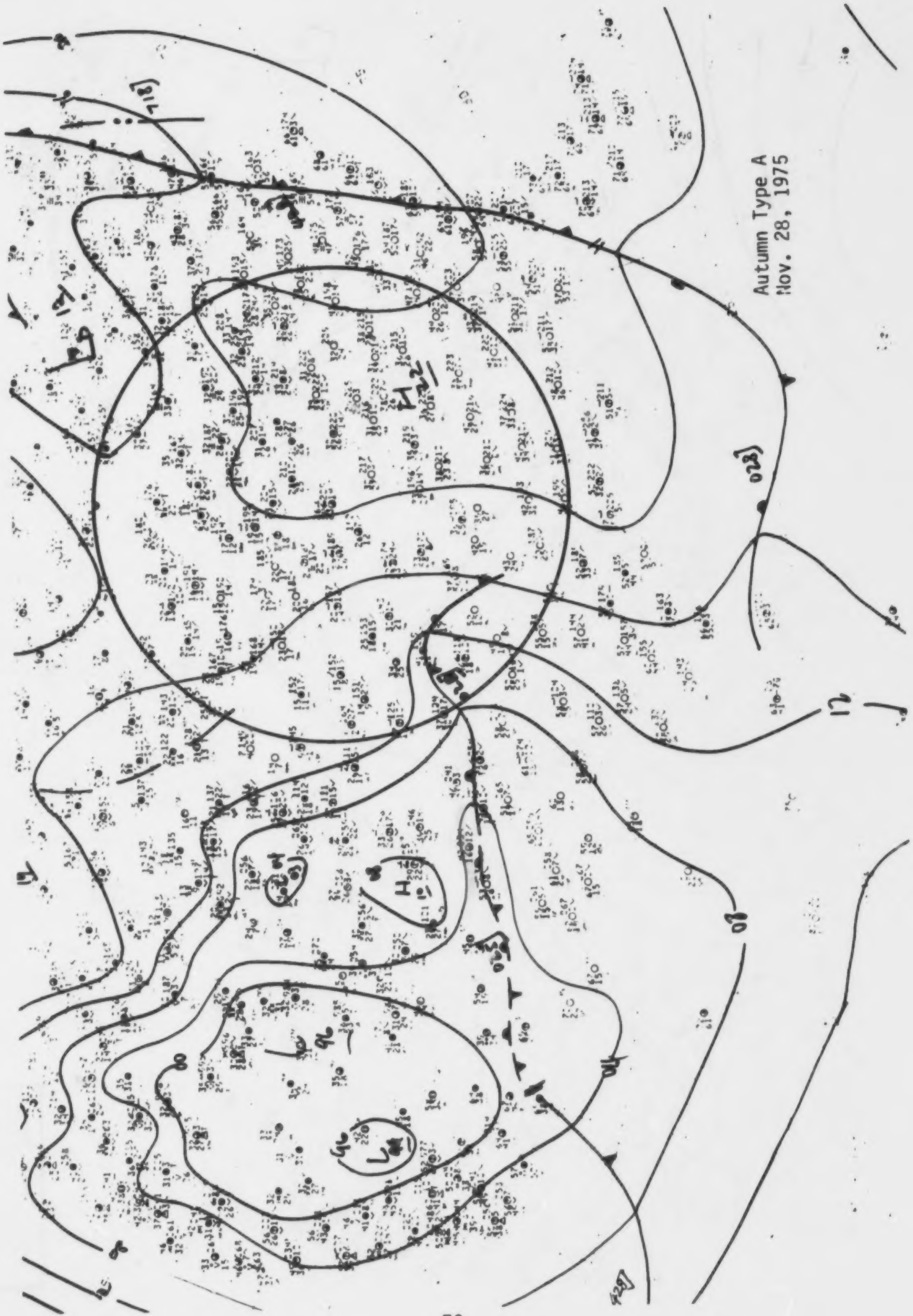
Reproduced from
best available copy.



Summer Type M
Aug. 20, 1975

Appendix A - Section 4

Autumn Map Types



Autumn Type A
Nov. 28, 1975

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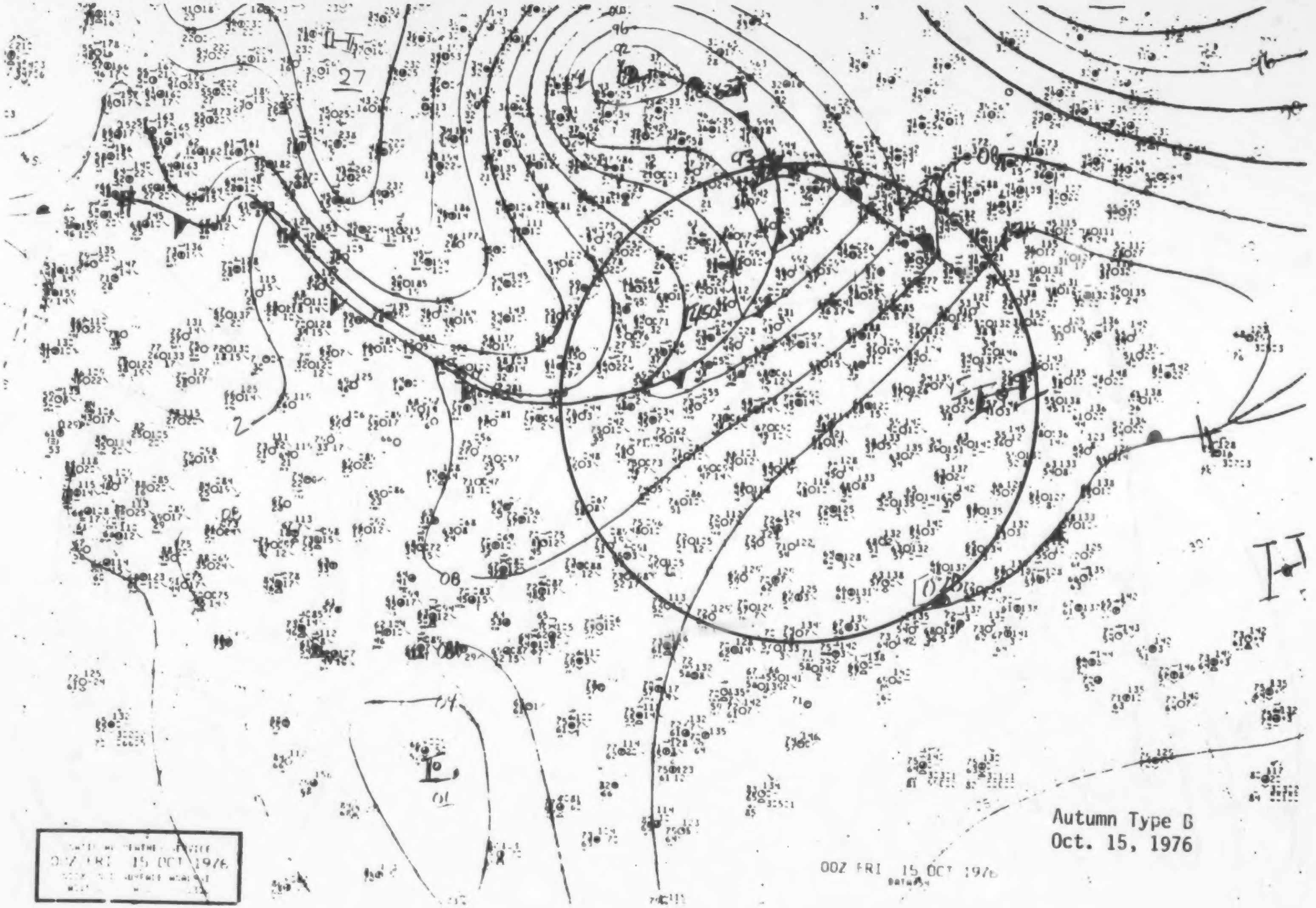
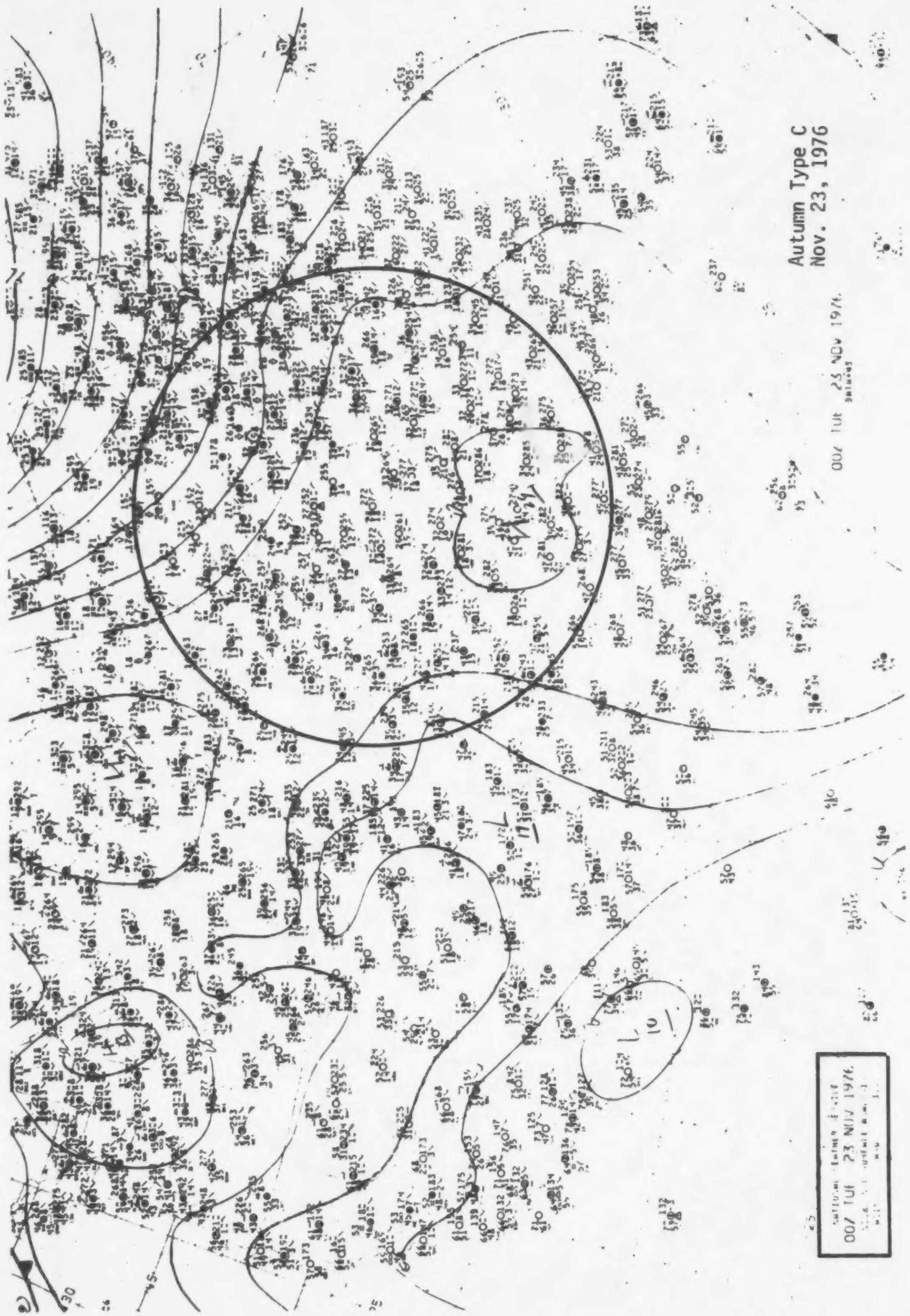
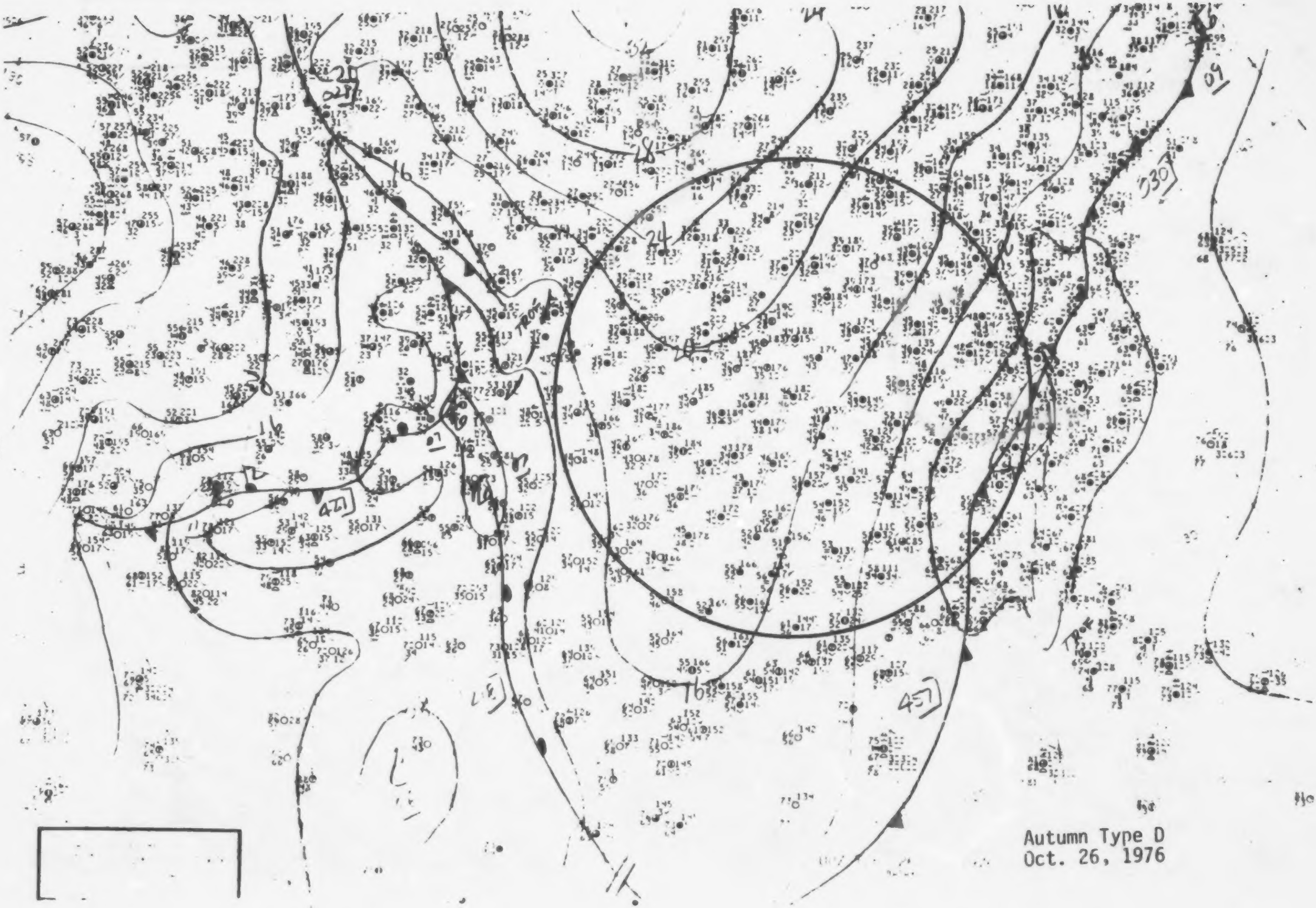
best available copy.



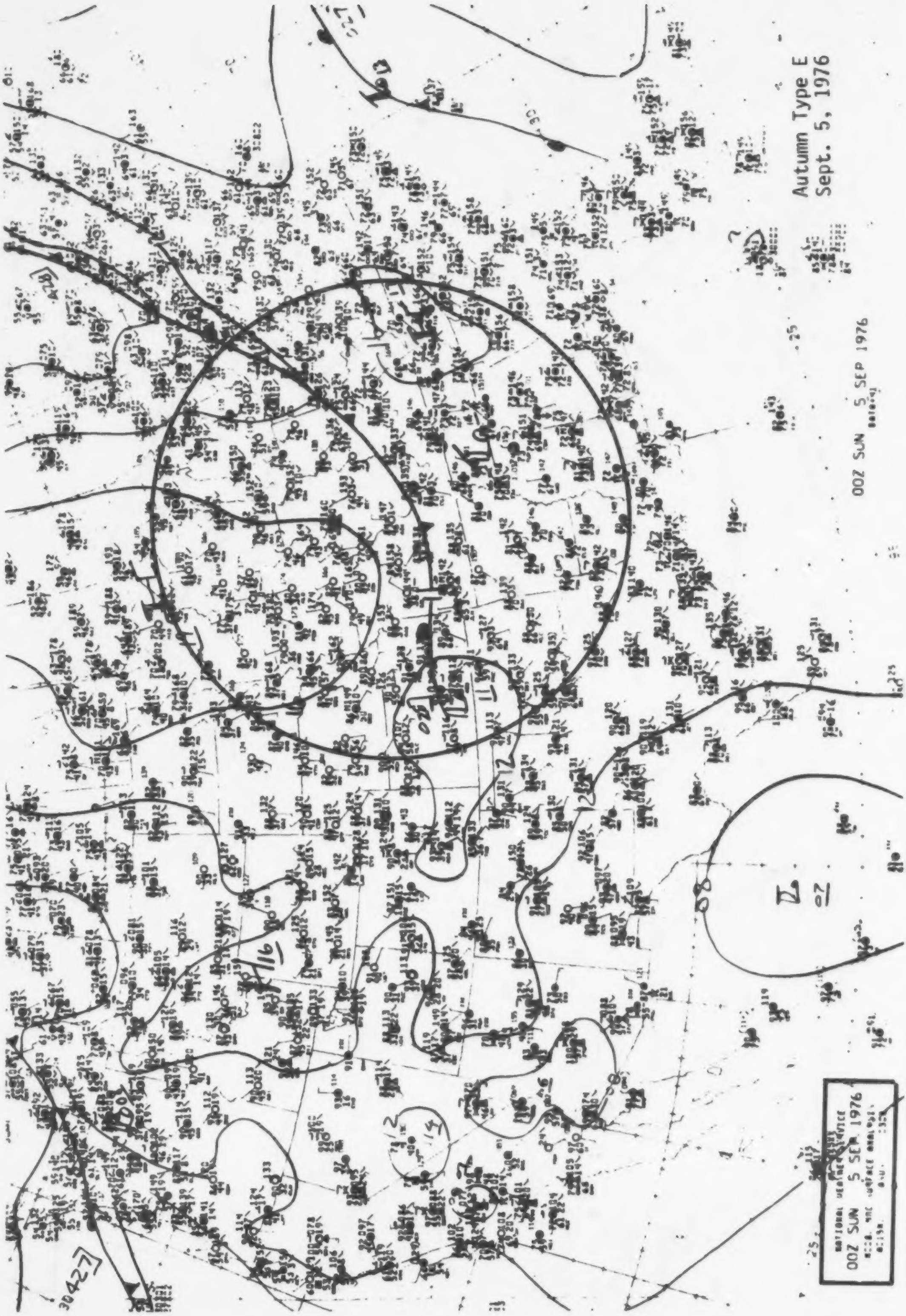
Autumn Type B
Oct. 15, 1976



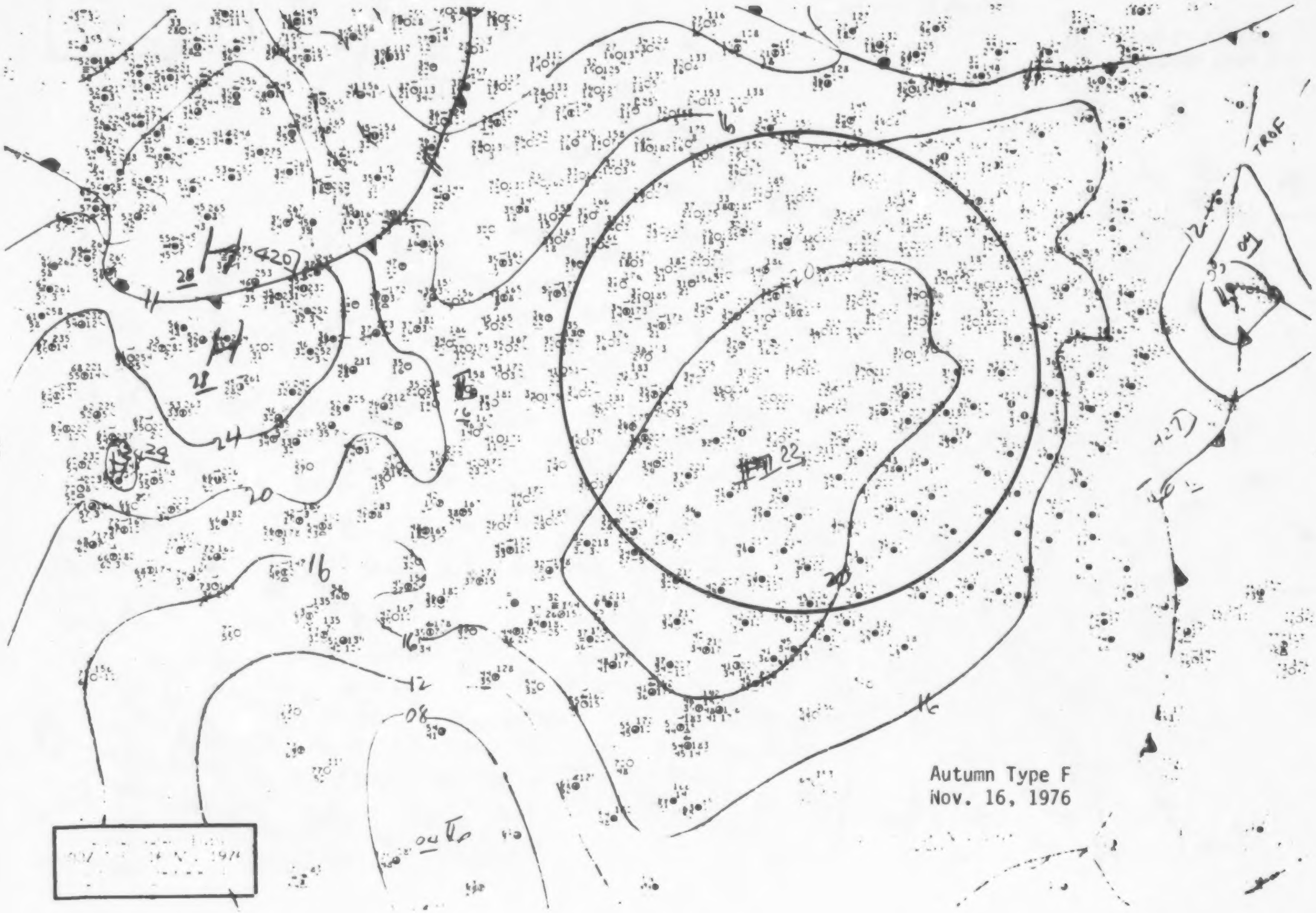
Autumn Type C
Nov. 23, 1976



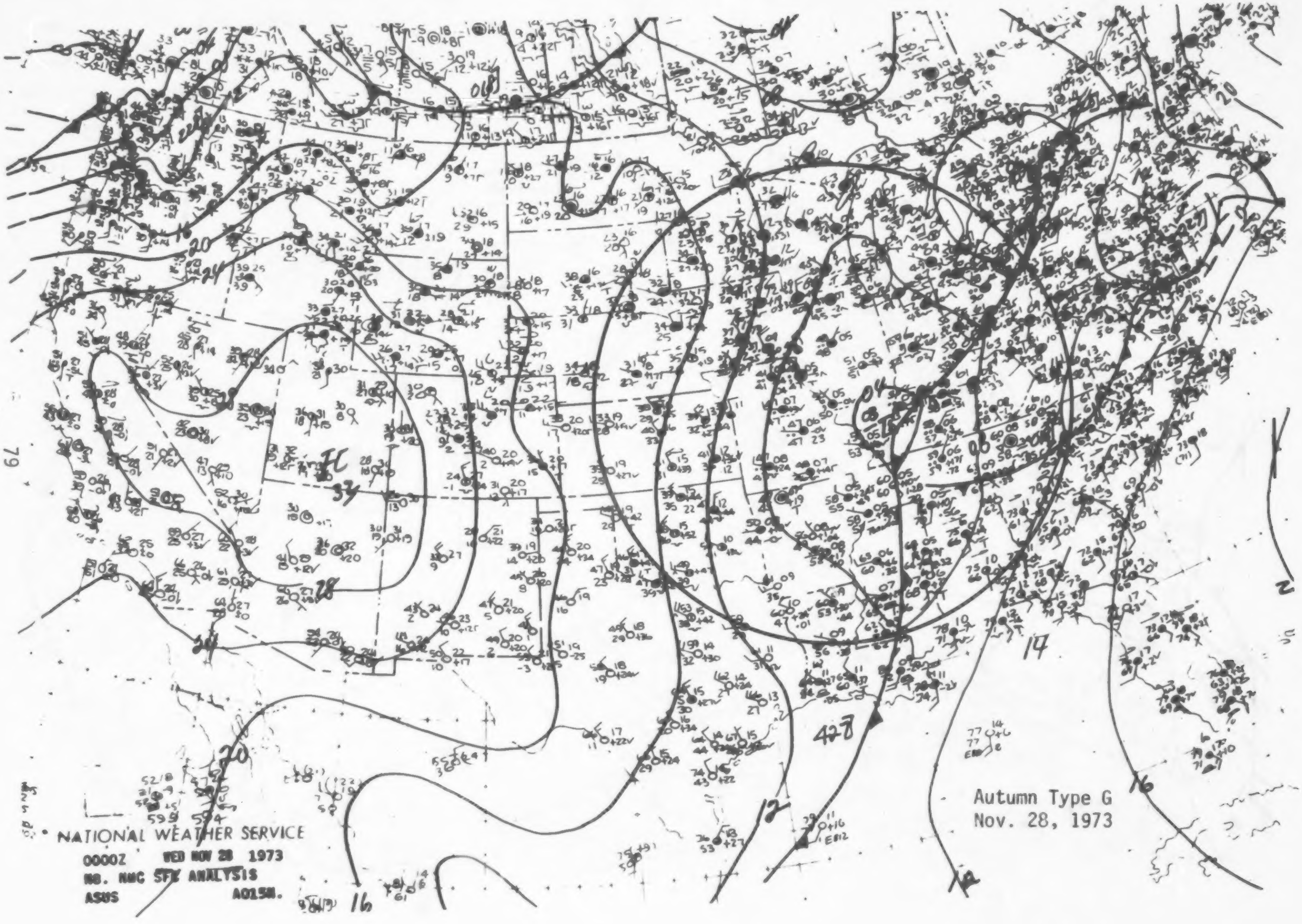
Autumn Type D
Oct. 26, 1976



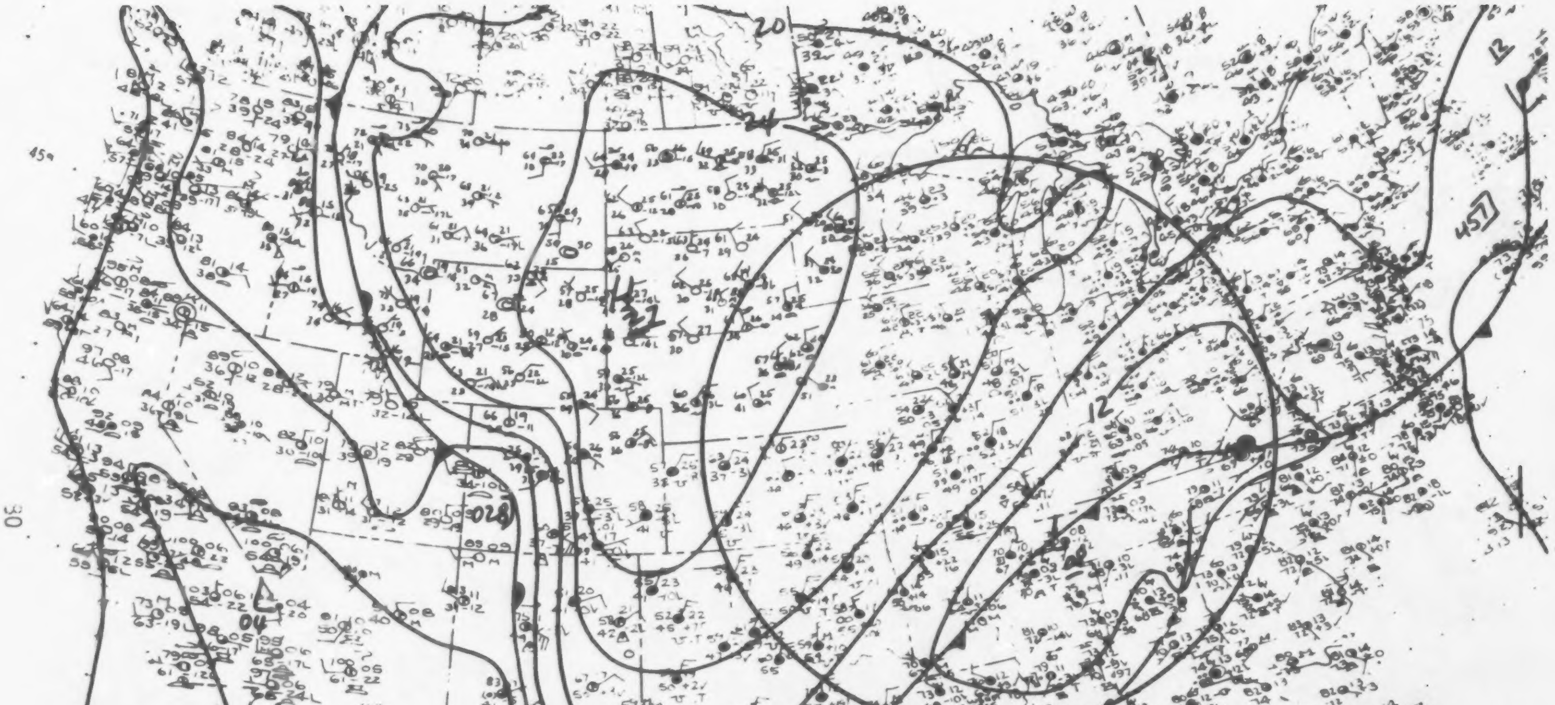
Autumn Type E
Sept. 5, 1976



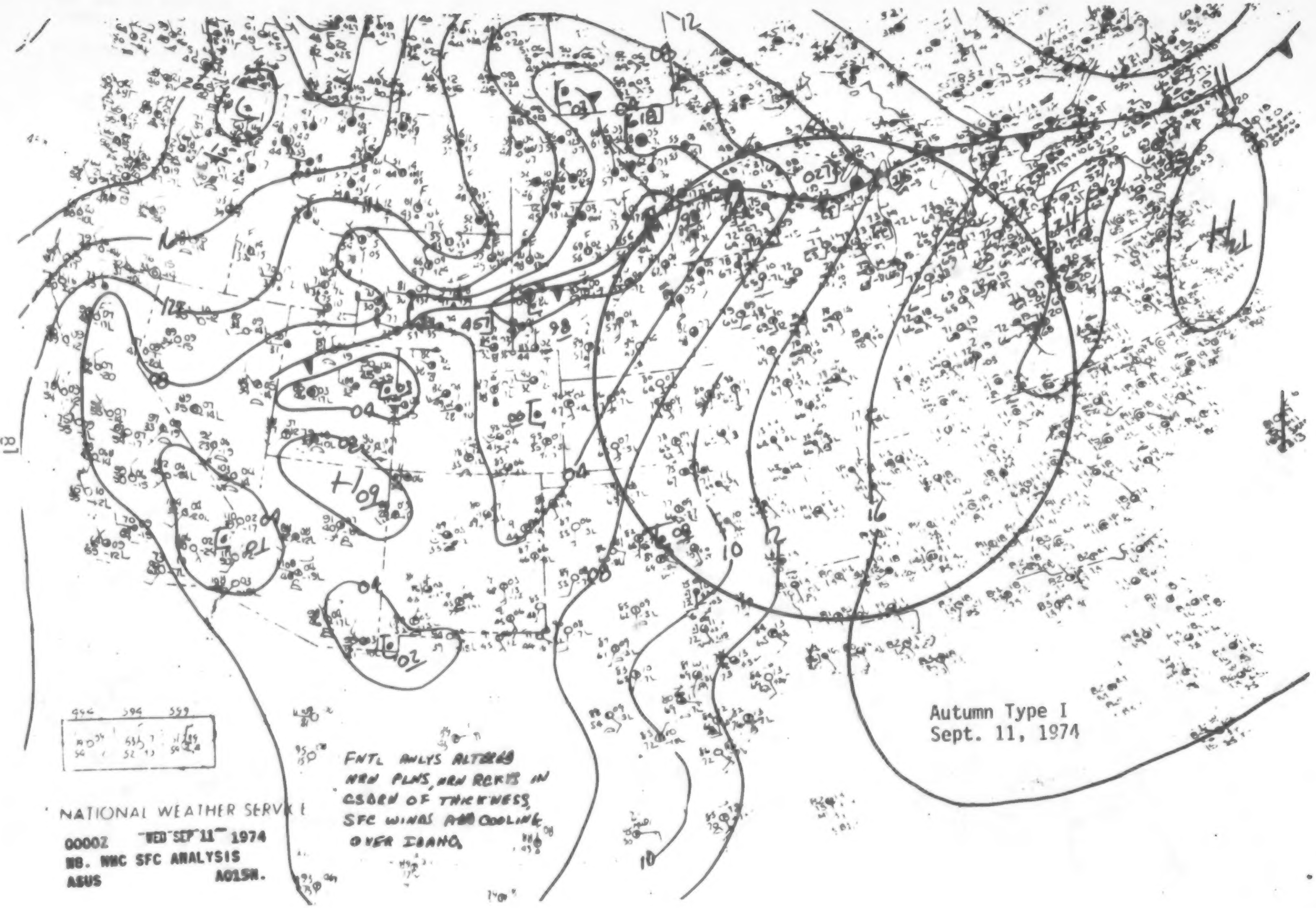
Autumn Type F
Nov. 16, 1976



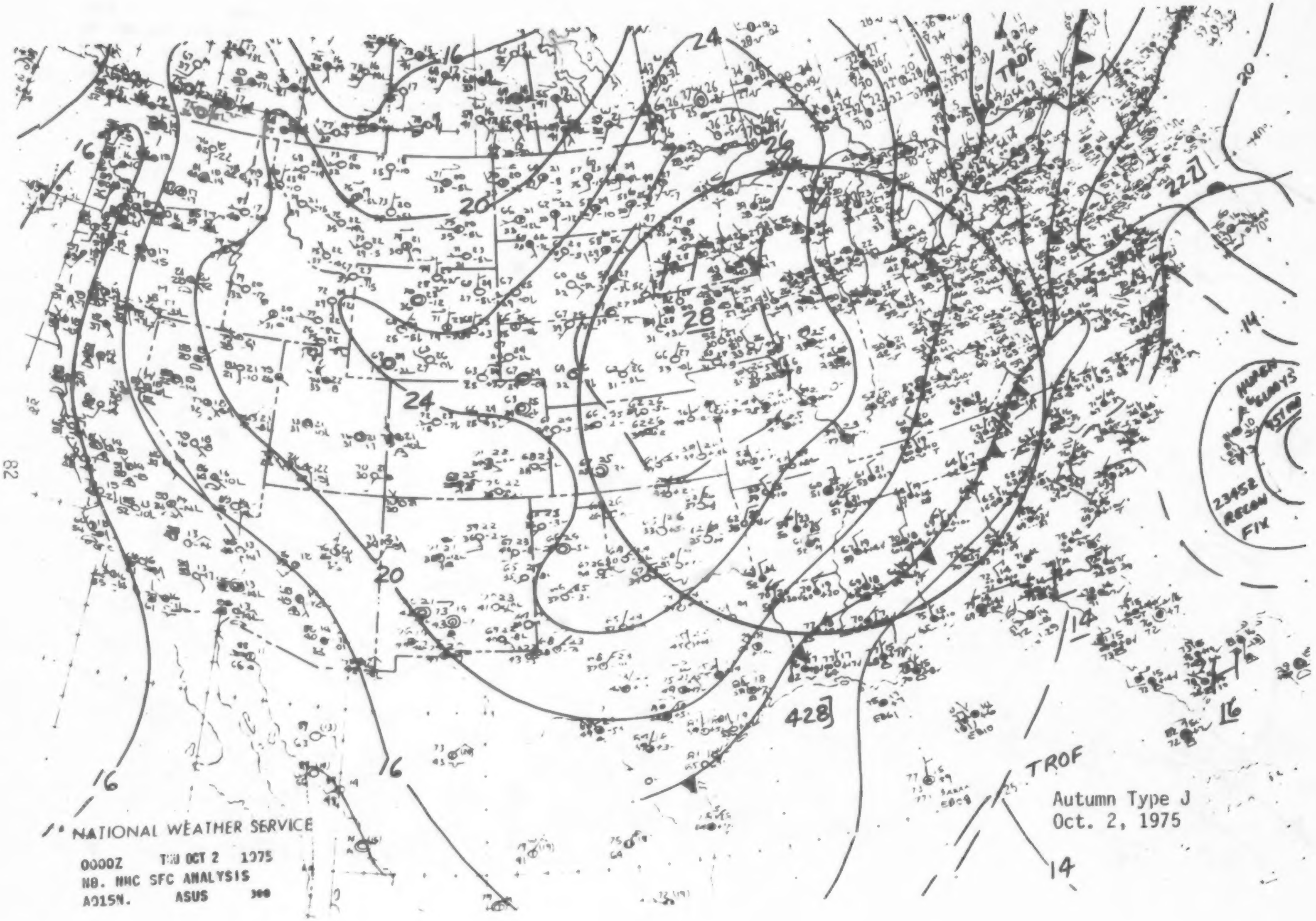
Autumn Type G
Nov. 28, 1973



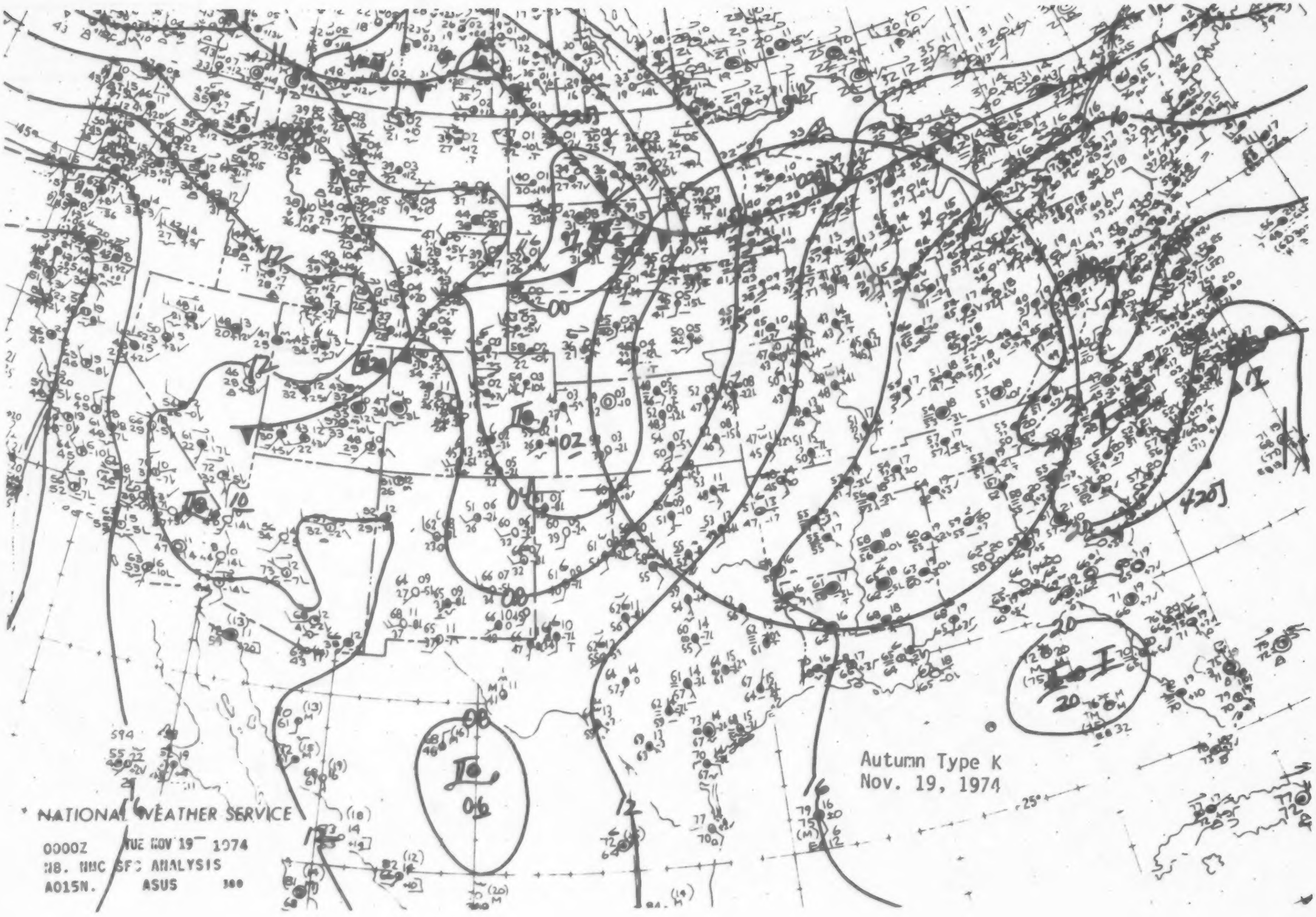
Autumn Type H
Sept. 3, 1974



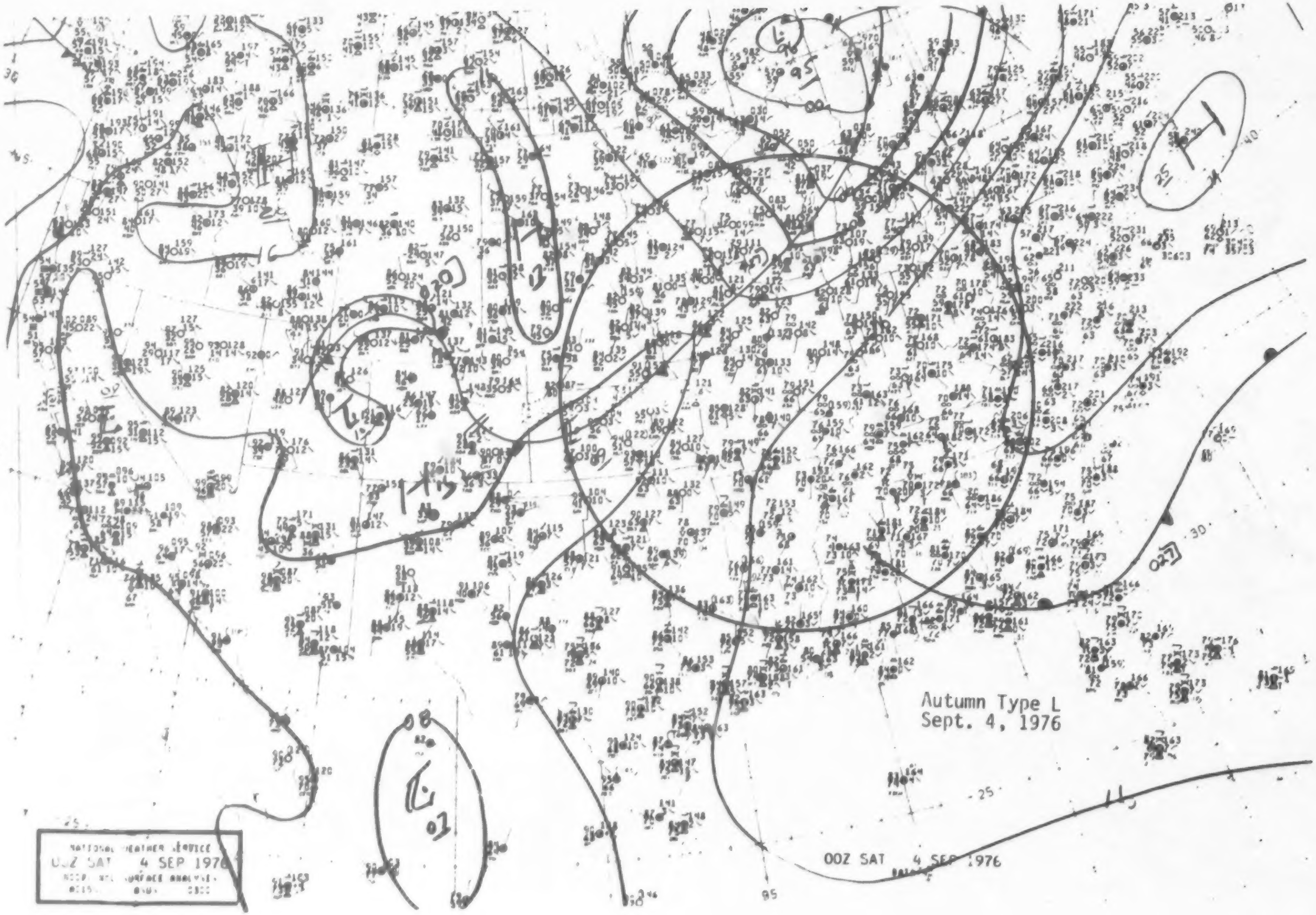
Autumn Type I
Sept. 11, 1974



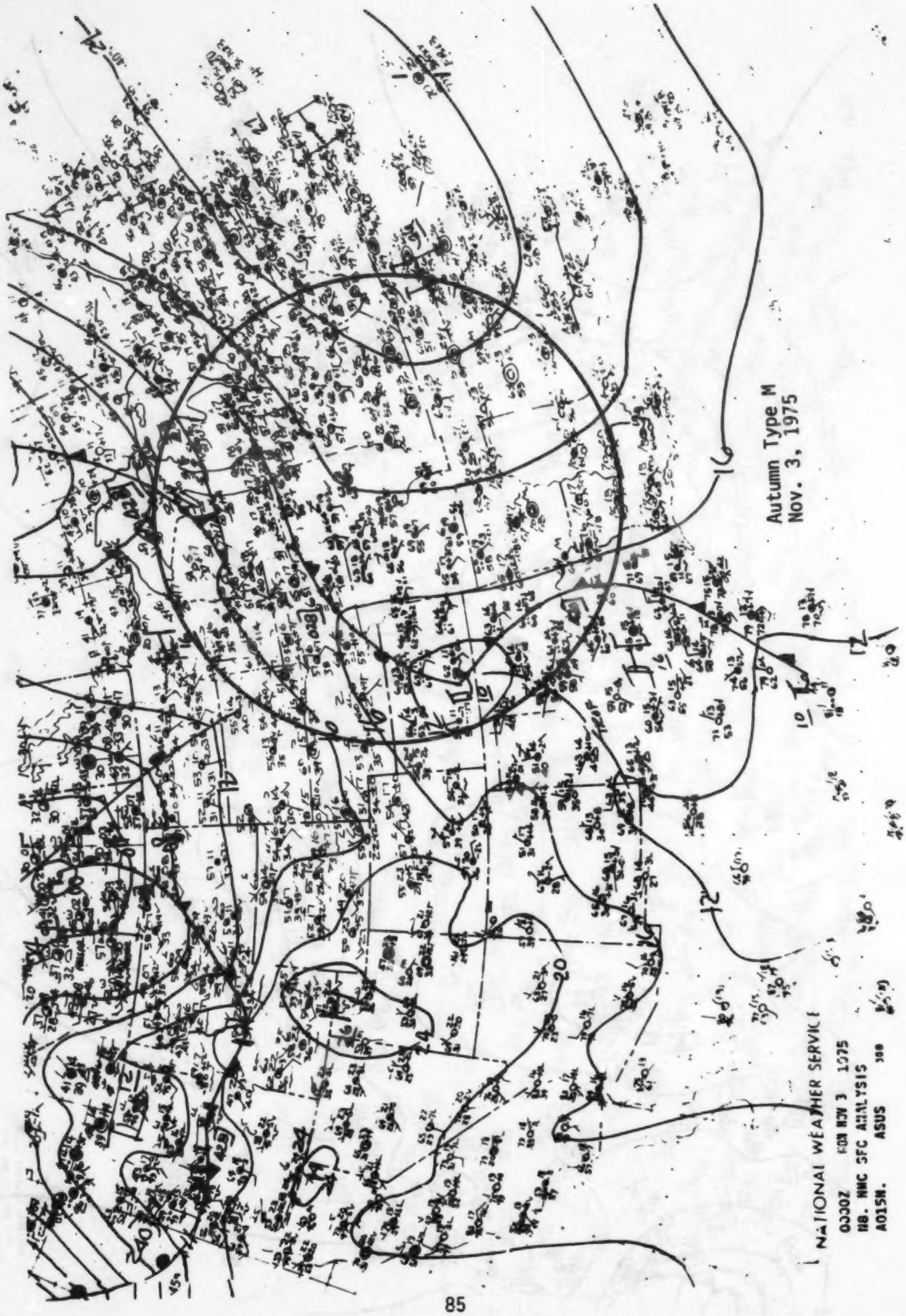
Autumn Type J
Oct. 2, 1975



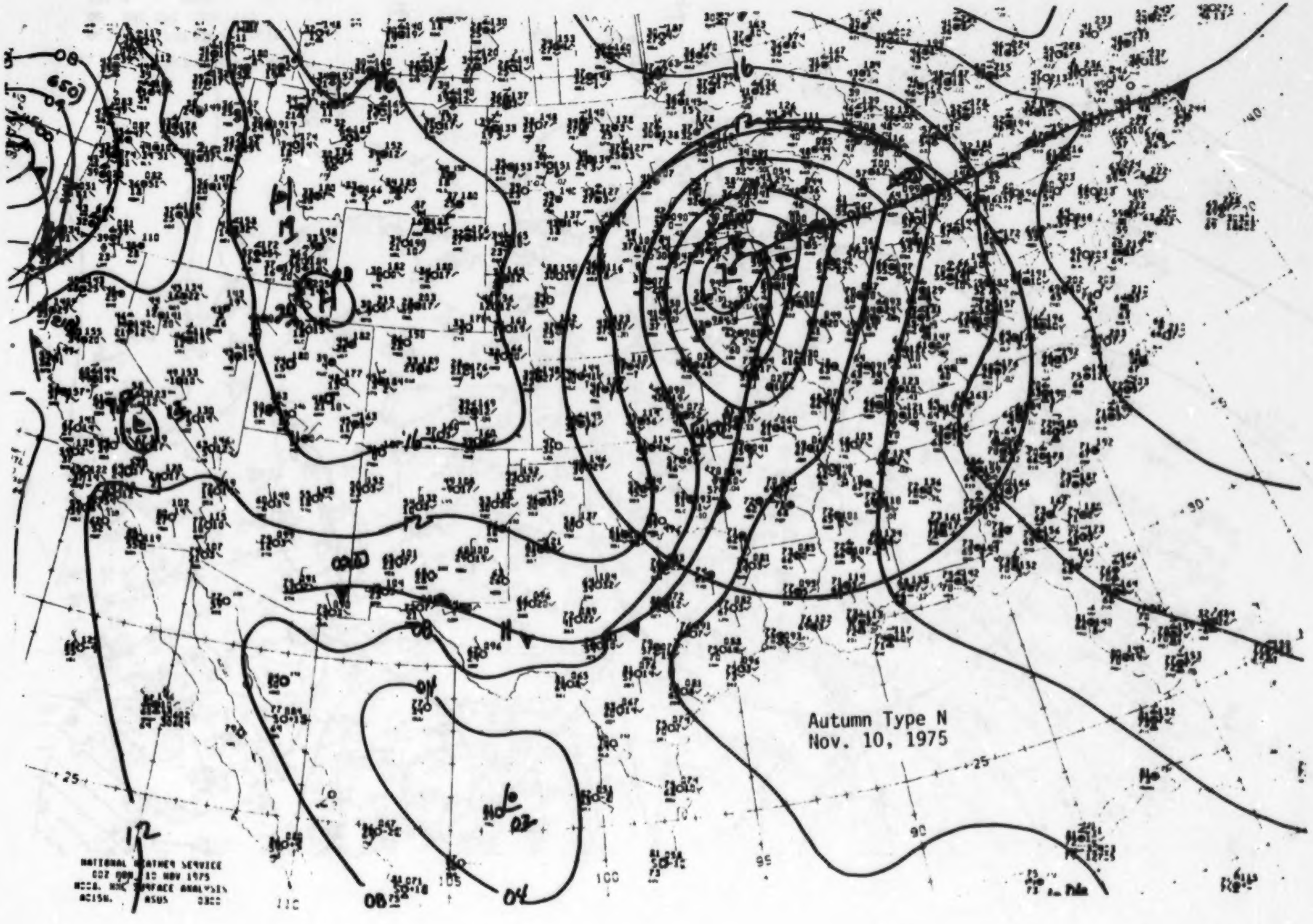
Autumn Type K
Nov. 19, 1974



Autumn Type L
Sept. 4, 1976



Autumn Type M
Nov. 3, 1975



Autumn Type N
Nov. 10, 1975